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Papers, Reports and Discussions

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HYDRO-ELECTRIC AND TRANSMISSION SESSIONS

COOPER, HUGH L. *The System of the Mississippi River Power Co.:* It is a far cry from the crude mechanism of the Chinese monjoli to the complex curves of the modern turbine. The evolution of the water wheel includes several different countries, many centuries of time and a roll of honorable names, among which our own James B. Francis is to-day the most prominent. A glacier came down from the northeast and dumped itself into the river above Keokuk, making the water-power development possible. Capital to construct the work was obtained in England, Germany, France, Belgium and Canada. The history of the project and a description of construction work, with a large number of lantern slides, conveyed to the audience a vivid impression of the immense proportions and great economic importance of this power undertaking which is second in interest only to the Panama Canal. 226

CREIGHTON, E. E. F. *Survey of the Conditions of Protection:* The paper is largely devoted to the subject of lightning arresters, their operation, application and latest developments. The multi-gap arrester still holds a predominant position in distribution work at or about 2300 volts, because of its lesser cost and of the fact that it can be made insensitive to arcing grounds and at the same time sufficiently sensitive to protect transformers. In order to get a high degree of protection for lightning transformers an arrester should be placed at each one, since if it is located only a few poles distant it will be ineffective against the concentrated and localized potentials due to lightning. In order to supply this increased demand and at the same time reduce the cost of the arrester, there has been developed a self-housed, self-contained form of the multi-gap known as the compression-chamber lightning arrester. In this type the shunt resistor has been discarded and more series gaps have been added, thus giving it better arc-extinguishing qualities. In aluminum arresters, the charging resistor represents a good investment. The qualities which make it a good discharger for lightning make it take a heavy current if the films are not in good condition. It is possible to place in series with such an arrester a resistor of considerable resistance without preventing it from taking its full charging potential, and this solves the problem of limiting the charging current to a reasonably small value, even though the films are badly dissolved. Another measure found advisable, in order to prevent arcing across the horngaps while charging, is the use of spring clips. Previous to January, 1912, an organic electrolyte was used in which a fungus growth was apt to appear. Since that date the operation of this type of arrester has been greatly improved by the use of an inorganic electrolyte. Ordinary pipes driven into earth well salted will give as good a ground connection as can be obtained. Most of the resistance of an earth connection lies in the immediate neighborhood of the pipe. Moisture is necessary to reduce the resistance, and the salt supplies this conducting moisture.
Discussed by Creighton, Lof, Paine, Roper, Rushmore. 157

DOWNING, P. M. *Report of Committee on Distributing Lines:* In the discussion of distributing lines, voltage is not considered as a limiting feature. The construction especially considered is that of the Western and Pacific Coast States, since these have done most of the pioneer work in distribution. Many changes have been made in methods of transmitting and distributing electrical energy. Voltages which a short time ago were not considered commercial possibilities are to-day being used not only on long transmission lines but very generally for distributing purposes. Rates are continually being reduced as the territory served increases, thus forcing operating companies to adopt a

construction the cost of which will be the minimum consistent with good service. A study of the voltages to be adopted in new territory is made and a comparison drawn between these and the demands of congested business centers. Star and delta connections, alternating and direct current, the use of batteries and of the turbine for both reserve and regulating purposes, all have attention in connection with the problem as a whole. Types of line construction have not changed greatly during the past few years. A satisfactory way of carrying two circuits on the same line of poles is given. The use of iron wire is suggested where load is small and voltage regulation not of great importance, as in reclamation and irrigation work. The rather severe requirements of the California Commission with regard to crossing construction are discussed. The relation of gross revenue to cost of investments in new line extensions is studied in its connection with long time contracts with customers. Sometimes the extension might be made on the basis of gross revenue for five or an even greater number of years equalling the investment. The percentage of power bills rebated averages from 20 to 25.
Discussed by Hamilton, McArthur, Negley. 239

GRIFFIN, R. A. *Poles and Pole Preservation:* In this paper the author gives data as to the annual consumption of wooden poles in the United States, citing the different woods used for poles and describing the qualifications of the various woods for this purpose. He calls attention to the necessity for greater attention to the question of a preservative treatment of the poles in the permanent lines of the operating companies, describes various methods of artificial treatment, and reports actual results thus far obtained in this country by these methods.
Discussed by Ballsley, Cole, Vanderpoel, Van Dyke. 143

KINGSBURY, ALBERT. *A New Type of Thrust Bearing:* The paper describes the construction and principle of operation of the author's patented type of thrust bearing, and gives data from tests and service. The bearing consists of a rotating collar sliding on stationary supporting surfaces, the whole being flooded with oil. The lubrication is automatic, no high-pressure pumps being used, but a low-pressure circulating pump with a gravity system is sometimes employed. The bearings are simple and durable in construction, can be made to carry great loads at high speeds, and run with very low friction and little wear.
Discussed by Parker, Rushmore. 131

MCCLELLAND, R. J. *Report of Committee on Membership:* The Committee has divided the country into districts and appointed a vice-chairman for each. Blank applications have been issued and an appeal is made for special effort on the part of the members of the section to increase the membership. Full and complete lists of all hydro-electric transmission companies, both in and out of membership have been available and marked effort should now be made to work up enthusiasm in this important section. The increase in membership during the past year has been small.
Discussed by Rushmore. 6

MAHONEY, J. N. *Developments in Protective Apparatus:* Improvements in oil and carbon circuit-breakers and lightning arresters due to the high voltage and generating capacities now in general use are described in a large number of types and sizes to meet various breaking capacity requirements at voltage up to 165,000 and conducting capacities up to 4000 amperes. Design and construction improvements

for moderate capacity and voltage service include porcelain insulating pillars clamped in position, contact details clamped thereto, use of removable separate arcing contacts, heavy steel plate tanks with lap-welded points, greater volume and head of oil, and strong tank supporting details. Medium voltage and capacity breakers have in addition, individual tanks per pole, on either a single multipole frame or individual tanks per pole, on either a single multipole frame or individual frames for each pole, "butt" type high contact pressure laminated brush contacts self-cleaning, "butt" type solid arcing tip situated to reduce the arcing to a minimum. High capacity, medium voltage breakers have elliptical or round tanks of the strongest construction, in which the metal is used in tension. Expansion chambers and appropriate vents are provided for the arc gases in all designs. For very high capacity and voltage a breaker having self-contained reactance cut into circuit on operation of the breaker is now standard. Carbon breakers are now made in standard capacities from 3 amperes to 24,000 amperes up to 1500 volts direct current. Modern types include the "butt" wiping form of laminated brush with metal secondary contacts and "butt" and wiping carbon final contacts. A new feature in a line of breakers for moderate conducting and breaking capacity is the use of pressed metal parts nearly throughout. The heavy service breakers, for the higher currents and voltages have several steps of increasing resistance in shunt to the main contacts, are provided with ventilating passages between the several brush units, which also reduces the skin effect on alternating current; they use the laminated or "bus bar" form of terminal stud. The aluminum electrolytic arrester has displaced all others for severe service. They are very rugged in design, and light pipe-frame supports are used for the auxiliaries and insulating linings in the tanks. Daily charging is the usual practice and the so-called "charging resistance" is used quite generally where the surges due to charging might cause trouble. An inorganic electrolyte and the annular form of tray have demonstrated their effectiveness.

Discussed by Mahoney, Van Kuran, Ward. 251

MARTIN, T. C. *Report of Committee on Progress:* The Report contains a general review of the events of the year in regard to the question of conservation and cites a number of references, public utterances of National and State officials on the subject, as well as various decisions and actions bearing on the points at issue. Attention is also directed to a number of engineering matters that are receiving consideration in the field, or to various ways in which attempts have been made to solve some of the problems. Several of the newer plants and systems in the transmission industry are then described, not only hydro-electric but some in which the energy of steam-driven plants is distributed in areas containing a large number of coal or other mines. Details are given with regard to some of the later projects in this country and Canada, and note is made of various foreign enterprises. Special note is made of the recommendation of official Swedish engineers to use the direct-current method for a 200 mile transmission from the Trollhattan Falls to Copenhagen, Denmark, in preference to the familiar 3-phase alternating-current method.

Discussed by Lof, Paine, Rushmore, Steinmetz, Wright. 18

RUSHMORE, D. B. *Report of Committee on Operation of Water Power Systems:* The rapid increase in hydro-electric developments which has taken place in recent years, and the growing importance of this power service is setting new operating standards before the managers of

these systems. It is now fully realized that the success of these developments can be obtained only by giving a most reliable and uninterrupted service, and the safeguarding of the different parts comprising the system, therefore, becomes of the greatest importance. The efficiency and reliability of operating forces is without question one of the greatest assurances for a satisfactory operation, and it is also intimately connected with the means which are provided for communication. The general layout of the system is naturally also an important factor. This refers to the capacities of the different generating stations, to the water conditions, to the characteristics of the load, etc. Practically no hydro-electric development with the capacity of installed apparatus above the rating at maximum stream flow is nowadays attempted without a steam station on the system. Such a steam station may be used as an auxiliary station at periods of low water, as a reserve in case of interruptions, or as a regulating station to take care of the variations in the load with the hydro-electric plant running at constant output. Consideration must also be given to the causes of disturbances and means for minimizing their effects. These are abnormal or so-called emergency conditions, and in treating of them, the failure of every piece of apparatus and part of the system must be consisdered as a possibility and a definite plan worked out for limiting the magnitude and area of such disturbances.
Discussed by Creighton, Lof, Paine, Roper, Rushmore. 167

RYERSON, W. N. *Address of Chairman of Section:* The report discusses the granting of water-power privileges by the government. A surprising lack of harmony has been noticeable between different Government departments and officials, all of which has produced very unsettled conditions. It was to be expected that a period of uncertainty must be passed through in the early development of these propects because they are of a distinctly new type, but it is time that a settled policy be adopted in connection with this work. In many sections there is a feeling that the States should exclusively control water-power developments within their borders. If this came to be the settled policy there would be considerable hope from the regulations imposed by State Public Service Commissions, which as a general thing have been quite fair. Mr. Ryerson refers to the project for building a State hydroelectric system in New York, and the part which the National Electric Light Association played at Albany in calling attention to the undesirable features connected therewith, particularly the financial aspects of the scheme. The adjoining hydroelectric system in Ontario was exposed as a disastrous financial failure and the foolhardiness of repeating this was pointed out with the result that Governor Sulzer vetoed the bill.. The chairman also calls attention to the evils of over-capitalization, which although chiefly associated with the past are still prevalent in some places to a certain extent. Regulation of capitalization by Public Service Commission has been wholesome on the whole. Referring to the Hydroelectric Section, he calls attention to the excellent attendance at its previous meetings, but, in contrast with this, to the fact that the actual membership is really quite small. He therefore urges stronger support and more close co-operation in developing the membership and work of the Section. 2

THOMAS, E. H. *The Failure of Conservation to Conserve:* The Bureau of Forestry of the Department of Agriculture, is hostile to development, especially in Alaska and in the Far West, and thus instead of using without wasting has wasted without using, which of course is not conservation in its broadest sense. Mr. Thomas shows the

difficulty experienced by private companies in obtaining water grants in the National Forest Reserve because the regulations are prejudicial to investors, and states that it is time for the country to place the administration of the public domain on a business basis. This can be done by employing practical business men to carry on the work instead of theorists and politicians. The latter, he holds, have brought conservation into disrepute and made it odious to the Northwest, which suffers most from the existence of an undeveloped and unprofitable wilderness.

Discussed by Rushmore. 8

VAUGHAN, J. F. *Report on Turbines:* No striking developments in any of the various forms of prime movers applicable to central-station use appear. However, much thought has been given to improving the efficiency of waterwheels and steam turbines, and an earnest effort has been made to develop an internally fired heavy-oil engine. Considerable attention has been devoted to boilers and boiler rooms with a view to raising their efficiency. Of the water-power units the vertical turbines seem to be most in favor at present owing in large measure to the improvements made in thrust bearings. The Kingsbury thrust bearing and the combined oil-pressure and roller form of bearing have been reported to give excellent results in operation. Steam turbines for driving station auxiliaries are reported to be bidding fair to supersede all other competitive apparatus. Curves submitted in the report show the relative steam economy of this type of auxiliary as compared with the high-pressure reciprocating steam engine. The following subjects have received further consideration: Runner Wear and Material, Testing of Water Wheels, Forms of Shop and Relief Valves. Mention is made of two valuable recent installations. The appendices contain detailed information of the principal points investigated. This is part of the Report of the Prime Movers Committee of which Mr. I. E. Moultrop is chairman, and Mr. Vaughan a member.

Discussed by Parker, Rushmore. 100

TECHNICAL SESSIONS

ABBOTT, W. L. *Report of the Committee on Underground Construction.* The report of the Committee on Underground construction deals this year exclusively with high-tension transmission cables, and discusses periodic testing, the carrying capacity, graded insulation, sector conductors, current-limiting reactances, protection of cables in manholes, parallel routes, trouble reports, practical hints as to operation, and specifications for paper and rubber-insulation cables for underground operating pressures in excess of 2000 volts. Considerable space is given to carrying capacity, and recommendation is made of a very decided increase in rating during the winter; also that the current rating be varied inversely with the voltage, on account of the heating in the insulation due to the leakage of current. Interest will probably be sharply aroused by the intimation that in paper cable American manufacturers are in some respects behind European, as evidenced, for example, by the bending test. In European cables the bending test is applied three times. American manufacturers consider as too severe a test of bending, first in one direction and then in the other, twice repeated, to a radius of six times the cable diameter. The specification presented in the report increases the radius of bending to 7½ times the cable diameter. The Committee hopes that the discussion of cable carrying capacity at the Convention will clear up some important but obscure points.

Discussed by Abbott, Cole, Davis. 638

DILLON, E. P. *Electric Railway Loads on Central Stations.* Attention is called to the desirability of railway loads, both city and interurban, as power customers for central stations. In some of the largest cities the problems have been very thoroughly worked out and excellent results obtained by combining the requirements of the two classes of service on one generating system. There still remain, however, many opportunities for improvement in this direction, and the problem, if carefully studied, will probably disclose possibilities not heretofore considered. The growing tendency to combine various communities over large areas under one generating system will naturally tend to increase the number of cases where central stations carry the railway load. Recent improvements in transforming apparatus—notably 60-cycle rotary converters—are strong factors in the development of this business, since practically all lighting companies which have a purely light and power load are now operating on the 60-cycle basis. Typical load curves are shown indicating an improvement in load-factor as the result of combining railway load with light and power load, and also demonstrating that the central station is not burdened with an extraordinary peak as a result of the railway load. The diversity factor between railway loads and central station loads when combined on one generating system is an important consideration, since the combined loads can be carried on a generating station of much smaller total capacity than if they were separate and carried on individual stations. Furthermore the necessary reserve capacity in the case of the combined station is also less. 698

ELDEN, L. L. *Report of the Committee on Electrical Apparatus.* There has been a continued tendency toward individual units of greater capacity and manufacturers have achieved higher rotative speeds in generating apparatus. Improved insulating material capable of operation at higher temperatures and of withstanding mechanical strains has contributed to the attainment of higher capacities. The use of reactances for limiting current has been found imperative in certain situations and the Report pays particular attention to desirable limitations in the installation of such equipment. Improvements have been made in 60-cycle rotary converters. The perfecting of details in electrical apparatus has secured greater attention. In an appendix 19 subjects are treated in detail, references being given in some cases to important papers on the subject. Manufacturers now indicate their ability to construct high-voltage generators of large capacities without employing autotransformers; 25,000-kilowatt generators are now standardized by American manufacturers. A table of important installations of current-limiting reactances is submitted, and a discussion on desirable amounts of reactance in various situations is included. Two methods of applying direct-coupled exciters to generating units are given. Standard applications of synchronous condensers for line regulation and power-factor correction are recited. Authoritative data regarding the use, care and life of various types of brushes are given. A new type of oil switch is described and reference made to improvements in existing types. A modification of the induction regulator is now available for outdoor service. A new form of reverse-current relay is described. Improved life of rectifier tubes is noted.

Discussed by Dillon, Durfee, Elden, Fishel, Kearns, Lincoln, Lof, McDowell, Moultrop, Schuchardt, Torchio. 493

FELLOWS, W. H. *Report of the Committee on Meters.* This report is accompanied by the third edition of the Code for Electricity Meters, which was prepared under the direction of a previous committee.

Information has also been gathered for use in a future revision of the *Electrical Meterman's Handbook* and a number of errata to the *Handbook* are given. The Committee has approved a standard form of dial face for watt-hour meters. This has also been approved by the Meter Committee of the Association of Edison Illuminating Companies and the co-operation of manufacturers in conforming to this standard has been assured. The report discusses the question of metering rapidly fluctuating loads and points out that the commutator type of meter is accurate under this condition and that the error in the induction type is negligible except in extreme cases. The connections of instrument transformers are discussed and a number of diagrams given. Maximum-demand devices receive considerable attention and various types of instruments for this purpose are described and illustrated, the recent development in the industry being pointed out. The effect of running induction meters designed for one frequency upon other frequencies has been investigated and test results are given showing the large errors involved. A bibliography of literature dealing with metering is included.
Discussed by Blood, Parker, Vaughen, Wilder. 304

HIBBARD, ANGUS S. *Telephonic Communication the Means of Control of Central Stations.* The advantages of an efficient organization directed by a single executive are pointed out and also the distinctive position of utility companies, which must meet load demands over which they have no control. Facilities have been developed for directing the operation of electric light and power companies from a central point by the use of telephones and supplementary appliances. As an instance of this, the equipment of the New York Edison Company is described in some detail. A system operator directs the operations of the entire system from the producing center at the waterside plants. He is in telephonic communication through both direct lines and lines of the telephone company with each substation, and also has direction of the operating men in the power house. A pilot board shows him the operating conditions of the entire plant, including the output of boilers and generators in the two power houses. A signaling system consisting of fire-alarm apparatus also reaches the substations, and communication with the city fire-alarm system enables the system operator to know when the high-pressure water stations will begin use of current for pumping. Reserve boilers and generators are always ready for service since load sometimes comes on the plant at rates up to 12,000 kilowatts per minute. The telephone switch-boards and intercommunicating system are described, as well as the general telephone service of the company. Details are also given of the telephone arrangements of the Commonwealth Edison Company, Chicago, where a load dispatcher is in direct communication with all the power plants and distributing centers. In Boston, Philadelphia and other cities similar arrangements are in use.
Discussed by Abbott, Loizeaux. 624

KENNELLY, DR. A. E. *Report of Committee on Measurements and Values.* Reference is made to recent actions of various engineering societies and committees recommending the abandonment of the "horse power" as a unit of power in engineering, and the substitution of the "watt" or some of its recognized decimal multiples—the "hectowatt," "kilowatt" and "myriawatt." Machines transforming power from one type to another, such as hydro-electric units or turbo-generator units, are more rationally and simply estimated as to efficiency, by rating both their input and output in the same unit. Since it is not desired

by any engineers to use either "British thermal units," "boiler horse power," or "mechanical horse power," for their powers at both the throttle and the generator terminals of, say, turbo-generators, it is natural and desirable to express both input and output in watts. Reference is also made to proposed recognition of the name "kelvin" in connection with a C. G. S. unit in the electrostatic system, Lord Kelvin having greatly developed both electrostatic measurements and the C. G. S. system.
Discussed by Steinmetz. 418

MacGahan, Paul. *Switchboard Instruments.* Both alternating-current and direct-current switchboard indicating meters for central-station service are described as well as new forms of alternating-current protective relays. The general features of interest common to all switchboard indicating instruments are accuracy, compactness, reliability, damping, ruggedness, accessibility, and simplicity. The purchaser should be guided by the principles of design and features of construction used, instead of by price and initial accuracy alone. The sources of error or unreliability may be classified as electrical, mechanical and observational. As the electrical sources of error on the best makes of instruments are now nearly all negligible for operating purposes, the mechanical sources of error are of greatest importance, the principal sources being: (1) excessive weight of movement, (2) insufficient ruggedness of movement, and (3) insufficient controlling force. A table is given showing the weight of movements, together with torques and ratios of torque to weight, for the principal makes of instruments. Errors due to observation are very important and can be reduced to a minimum by making scales as long as possible without increasing the area occupied on the panel. A table shows the inches per volt deflection on the scale at the normal load on several different kinds of instruments. Previous attempts to economize switchboard space by reducing the meter diameter were unsatisfactory because they resulted in scales of insufficient length, and other methods of economizing space by recourse to curved dials, as in edgewise meters, were likewise unsatisfactory. The induction principle makes possible the successful seven-inch meter, as the scale is two or three times as long as in the nine-inch meter. As the large instruments offer no advantages over these seven-inch types, the latter will probably be used to a greater extent in the future. The effect of stray fields from busbars upon the permanency of the magnets in direct-current D'Arsonval type of meters is decreased, and tests show that magnetic shielding is of no value in avoiding demagnetization when heavy short-circuits occur. A type of construction is shown in which the magnets are located so as to be practically unaffected by the stray fields. Four different variations of new alternating-current induction type relays are described, giving protection against overloads and reverse currents.
Discussed by MacGahan, Osborne, Smith. 599

Merriam, E. B. *Switching Apparatus for Rural Installations.* The recent advent of outdoor switching apparatus has opened to electricity supply corporations a wide field of application. The new consumers thus made possible include small towns, mines, quarries, farms, irrigation and many other developments which have heretofore relied for power on isolated plants or manual labor. The equipments perfected for this service include complete lines of semi-portable and portable sub-stations for supplying power from existing high voltage transmission lines. They are made up of

inexpensive but reliable outdoor fuses, switches, transformers, switch houses and other necessary devices whose construction and application are discussed in this paper. 739

MOULTROP, I. E. *Report of Committee on Prime Movers.—Water Power*—Recent improvements in thrust bearing and runner design have eliminated certain objections to the vertical unit. The following subjects have received further consideration:—Runner wear and material testing of water wheels and forms of stop and relief valves. Mention is made of two notable recent installations. The appendix contains detailed information on the principal points investigated. *Steam Power*—Developments in the steam turbine during the past year have been treated at some length, as well as the development of steam turbine-driven auxiliaries. The subject of fuel oil is treated quite completely. Various kinds of apparatus for determining the efficiency of the steam plant are discussed in considerable detail and special attention has been given to the boiler house equipment. *Gas Power*—A very complete résumé of the general petroleum situation is given in the report, as well as the fluctuations in the cost of this fuel. The development of heavy oil engines is treated at some length and specifications are given for suitable oil for these engines. The developments of the Humphrey gas-power pump are reported upon and mention is made of the progress in development of the gas turbine. A partial digest of the recent engineering publications bearing on the subject of prime movers and accessory apparatus, is included at the end of the report.
Discussed by Abbott, Moultrop. 425

OSGOOD, FARLEY. *Report of the Joint Committee on Overhead Line Construction.* The report consists mainly of specifications for overhead crossings of electric light and power lines. The specifications formerly proposed have been somewhat altered and have now been agreed upon by the High-Tension Transmission Committee of the American Institute of Electrical Engineers, the Committee on Power Distribution of the American Electric Railway Association, the Committee on High-Tension Wire Crossings of the Association of Railway Telegraph Superintendents ,and the Subcommittee on Electricity of the American Railway Engineers and Maintenance of Way Association. The Committee recommends that the specification be supplemented by others covering required construction for constant-potential lines of over 5000 volts necessarily constructed parallel to or in proximity with lines of telephone or telegraph wires. Power-line construction in such cases should equal in mechanical and electrical strength that required for crossings. It is proposed to change the title of the committee to National Joint Committee on Overhead Line Construction.
Discussed by Coleman, Coombs, Davis, McClellan, McGee, Paine, Roper, Sawin, Stevenson. 558

RANDALL, J. E., and EDWARDS, E. J. *Recent Progress in the Art of Lamp Making.* The past year has witnessed progress in the incandescent lamp industry in improving the standard product, and developing new types of lamps. The rated specific consumption of regular lamps has been reduced about 0.15 watt per candle on the larger lamps through the careful use of chemicals which retard the blackening of the bulb. Such improvements have made it practicable to employ smaller bulbs for a given wattage, notably in the case of 40 and 60-watt lamps. The most striking new development is exemplified in the use of filament wound into a helical coil, which coil may be mounted on supports in various ways. The coil construction allows a great length of filament to be put

into small compass without appreciable leakage between adjacent turns. This makes it possible to construct lamps to focus closely, as is required for small stereopticons, sidewalk projectors, street railway and electric vehicle headlights, and the like. The coiled filament may be mounted on small supports of the regular spider type and placed in miniature bulbs of the various candelabra and decorative types. It may be placed in a tubular bulb to make a showcase lamp, which consists of a single straight section of coiled filament carried through the middle of the bulb, the return circuit being made through the heavy wire support.
Discussed by Howell, Macbeth, Wilcox. 376

REED. E. G. *The Latest Developments in Distributing Transformers.* The most important recent improvements in distributing transformers have been in relation to the materials and methods of winding and insulating the coils. This has resulted in higher factors of safety between the actual disruptive strength of the insulation and the commercial tests applied. In some cases the commercial disruptive tests have actually been increased over those formerly used, due to the greater insulation strength secured, and the qualities of ruggedness, durability and safety in operation have been correspondingly enhanced. A further result of these improvements has been to increase the operating efficiency of the transformer. The first part of this paper discusses these insulating materials and the scientific method used in their application as related particularly to the standard line of 2200-volt distributing transformers. The second part of the paper relates to the improvements in performance which these materials and processes have made possible. The insulation of a transformer consists of three main parts: (1) between turns and layers of the winding, (2) between the high and low tension windings, (3) between the windings and metallic parts of the transformer. Since the insulation of a transformer is no stronger than its weakest part, its various elements must be considered in their relation to each other. In other words, the factor of safety between the commercial tests applied and the ultimate strength of the various parts of the insulation should be consistent. The improvements in winding and insulating discussed in the paper, in the main result from the guttered winding going with the machine type of coil, the use of improved machine-formed insulating barriers and the arrangement of the oil circulating ducts. This has given lower iron and copper losses and at the same time the insulation has been improved. The improved insulation, aside from making lower iron and copper losses possible, has permitted an increase in the values of the commercial tests used. This in turn results in increased reliability and makes for long life and low depreciation of the transformer.
Discussed by Fishel. 609

RUDD, H. H. *Transformers for Power Transmission.* The great tendency at the present time toward centralization of power is making many interesting problems in power distribution. The voltage chosen for distribution must be high enough for economical transmission and not so high that the cost of a complete substation installation makes it impractical to install those of small and moderate capacity. The development of the outdoor transformer with the necessary switching and protective devices has made it possible to use installations of small capacity at a high voltage and at very moderate cost. In the paper is given a curve of costs for installations of different capacities for various voltages. It shows that where the transmission lines feed a number of small communities, the economical voltage

is 22,000 or 33,000. It is shown that the saving by the use of an extremely small size transformer is so slight in comparison with the total cost of installation as to be negligible. It is pointed out that there is a wide variance in characteristics demanded by the different power stations, more particularly as regards voltage variation and taps. Special emphasis is laid on the great extensions that are being made in the use of all transformers and the need of standardization as regards taps. Such standardization will result in much good to the industry at large, to the manufacturers and to the customer. 687

SMITH, FRANK W. *Report of Lamp Committee.* The work of the Committee has been confined largely to publishing in the Association *Bulletin* articles on the incandescent lamp situation. The Committee has felt that this method of furnishing information month by month is of value to the member companies. A list of articles is given and they are reproduced in full as an appendix. Under "Lamp Sales" is shown the total output of incandescent lamps for domestic use. indicating the increase in percentage each year since 1907. The total sales for 1912 increased 6 per cent over 1911, the gem and mazda types representing about 75 per cent of the total. The sale of the carbon lamp is rapidly decreasing, being less than 50 per cent of the preceding year, and conditions indicate the rapid substitution of the metallized and mazda lamps for the carbon. By reference to the table and curve forming a part of the report the general trend in this direction, as well as other detail, will be apparent. Under "Development" the report undertakes to show the progress made by manufacturers throughout the year. This has been very rapid, improving as they have the quality of the tungsten-filament lamps. These improvements are set forth in some detail. As to prices, the tendency is continually downward. The development throughout the country in the electric sign business has been very marked, as set forth. The new types of lamps standardized throughout are listed in detail. The trade name "mazda" has now been adopted generally by American manufacturers for the tungsten-filament lamp. The popularity of the lamp under this trade mark is being rapidly furthered through a liberal policy in its introduction on the part of central stations and wide publicity given by the manufacturers. Certain suggestions and recommendations are included in the report.
Discussed by Howell, Macbeth, Willcox. 358

STEVENSON, T. K. *Overhead Distribution Circuits for Series Arc Lighting.* Referring to the several kinds of wire commercially available for overhead distribution circuits, the author finds that copper-clad steel wire excels for certain classes of service. This wire is made by dipping a steel billet into a bath of supermolten copper which is so hot that it heats up the billet to a point where it actually absorbs a certain amount of copper. When the surface of the steel begins to melt, the billet is withdrawn and this surface is wet down with a copper-iron alloy. The alloy-coated billet is then placed in a mold and a coating of copper cast around it, the copper welding to the copper-iron alloy. By this process there is no surface contact between the pure copper and pure steel, the former grading into the latter through a series of copper-steel alloys. Three varieties of this reinforced wire are made, having conductivities of 30, 40 and 47 per cent that of pure copper. Wire of this kind finds its field of usefulness in those cases where fair electrical conductivity has to be combined with great mechanical strength and resistance to corrosion. Weather-

GENERAL INDEX

PROCEEDINGS OF THE THIRTY-SIXTH CONVENTION 1913

NOTE—In the Author Index will be found author's names and synopses of papers and reports, the latter under names of chairmen.

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CONVENTIONS OF THE ASSOCIATION

First	Chicago, February 25, 26, 1885
Second . . .	New York, August 18, 19, 20, 1885
Third	Baltimore, February 10, 11, 12, 1886
Fourth . . .	Detroit, August 31, September 1, 2, 1886
Fifth	Philadelphia, February 15, 16, 17, 1887
Sixth	Boston, August 9, 10, 11, 1887
Seventh . . .	Pittsburgh, February 21, 22, 23, 1888
Eighth . . .	New York, August 29, 30, 31, 1888
Ninth	Chicago, February 19, 20, 21, 1889
Tenth	Niagara Falls, August 6, 7, 8, 1889
Eleventh . . .	Kansas City, February 11, 12, 13, 14, 1890
Twelfth . . .	Cape May, August 19, 20, 21, 1890
Thirteenth . .	Providence, February 17, 18, 19, 1891
Fourteenth . .	Montreal, September 7, 8, 9, 10, 1891
Fifteenth . . .	Buffalo, February 23, 24, 25, 1892
Sixteenth . .	St. Louis, February 28, March 1, 2, 1893
Seventeenth . .	Washington, February 27, 28, March 1, 2, 1894
Eighteenth . .	Cleveland, February 19, 20, 21, 1895
Nineteenth . .	New York, May 5, 7, 9, 1896
Twentieth . .	Niagara Falls, June 8, 9, 10, 1897
Twenty-first . .	Chicago, June 7, 8, 9, 1898
Twenty-second .	New York, May 23, 24, 25, 1899
Twenty-third .	Chicago, May 22, 23, 24, 1900
Twenty-fourth .	Niagara Falls, May 21, 22, 23, 1901
Twenty-fifth . .	Cincinnati, May 20, 21, 22, 1902
Twenty-sixth .	Chicago, May 26, 27, 28, 1903
Twenty-seventh .	Boston, May 24, 25, 26, 1904
Twenty-eighth .	Denver-Colorado Springs, June 6, 7, 8, 9, 10, 11, 1905
Twenty-ninth .	Atlantic City, June 5, 6, 7, 8, 1906
Thirtieth . . .	Washington, June 4, 5, 6, 7, 8, 1907
Thirty-first . .	Chicago, May 19, 20, 21, 22, 1908
Thirty-second .	Atlantic City, June 1, 2, 3, 4, 1909
Thirty-third . .	St. Louis, May 23, 24, 25, 26, 27, 1910
Thirty-fourth .	New York, May 29, 30, 31, June 1, 2, 1911
Thirty-fifth . .	Seattle, June 10, 11, 12, 13, 14, 1912
Thirty-sixth . .	Chicago, June 2, 3, 4, 5, 6, 1913

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Hydro-Electric and Transmission Sessions

HYDRO-ELECTRIC AND TRANSMISSION SESSIONS

FIRST HYDRO-ELECTRIC AND TRANSMISSION SESSION—
JUNE 4, 10 A. M.

1—Address of Chairman of Section. W. N. RYERSON

2—Report of Committee on Membership. R. J. McCLELLAND

3—Paper: *"The Failure of Conservation to Conserve."* E. H. THOMAS

4—Report of Committee on Progress. T. C. MARTIN

5—Report on Turbines. J. F. VAUGHAN

6—Paper: *"The New Type of Thrust Bearing."* ALBERT KINGSBURY

SECOND HYDRO-ELECTRIC AND TRANSMISSION SESSION—
JUNE 5, 2.30 P. M.

1—Paper: *"Poles and Pole Preservation."* R. A. GRIFFIN

2—Paper: *"Survey of Conditions of Protection."* E. E. F. CREIGHTON

3—Report of Committee on Operation of Water Power Systems. D. B. RUSHMORE

4—Paper: *"Factors Producing Reliability in the Suspension Insulator."* A. O. AUSTIN

5—Lecture: *"The System of the Mississippi River Power Co."* HUGH L. COOPER

THIRD HYDRO-ELECTRIC AND TRANSMISSION SESSION—
JUNE 6, 10 A. M.

1—Report of Committee on Receiving Apparatus. M. R. BUMP

2—Report of Committee on Distributing Lines. P. M. DOWNING

3—Paper: *"Developments in Protective Apparatus."* J. N. MAHONEY

4—Paper: *"Transmission Line Construction."* R. D. COOMBS

FIRST HYDRO-ELECTRIC AND TRANSMISSION SESSION

WEDNESDAY MORNING, JUNE 3

The meeting was called to order at ten o'clock by Chairman W. W. Freeman.

THE CHAIRMAN: It seems necessary to begin these meetings with a comparatively few members. I am very sorry that there are not more present to hear the Address of the Chairman of the Section, but he prefers that we proceed rather than delay the meeting further. I have pleasure in presenting Mr. W. N. Ryerson, of Duluth.

ADDRESS OF THE CHAIRMAN OF SECTION

In opening the third meeting of the Hydro-Electric and Power Transmission Section of the National Electric Light Association, your Chairman desires first of all to express his sincere appreciation of the loyal and unselfish work which has been done throughout the year by the chairman and members of the various committees appointed and whose work will be presented to you in the reports and papers to come before the sessions of the Section. Particularly are thanks due to the Western members whose interest was so greatly aroused by our last convention on the Pacific Coast.

The last year has witnessed a departure from the "do-nothing" policy of the national government in that under the former Secretary of the Interior, Mr. Fisher, permits have been granted for the use of government lands by power companies and rules published which define, to some extent, the general policy of that department towards such enterprises. It is unfortunate, to say the least, that, due largely to our system of government, it seems to be impossible to predict whether such rules as are now in force will long remain unchanged in important particulars. Especially is it to be regretted that thus far no precedents have been established as to the attitude to be taken toward the development of water powers on navigable streams, and that there is serious disagreement among the members of Congress on this question, which would seem to make it impossible for many undeveloped powers to be put to beneficent use under any terms, whether fair or unfair. Lack of harmony between the advocates of centralized governmental control and States' rights is largely responsible for this condition of affairs, coupled with which is fear on the part of many legislators of going contrary to the ideas of the Pinchot school of conservationists. Instances have been known where corporations were ready and willing to pay a liberal sum for the privilege of development, but were prevented from obtaining their permits by advocates of the policy of allowing each State to determine such matters for itself—a shining example of the present unsettled state of affairs. Fortunately, the educational work so successfully carried on by public service corporations and by right-thinking citizens has done and is doing

much to change public opinion regarding such matters. There have been entirely too much secrecy and "gum shoe" methods used by corporations in the past, and the public has become convinced that exorbitant profits are being realized by every hydro-electric project, whereas those of us who have been intimately connected with the business know that in all but a few minor instances the exact contrary is true. The State Public Service Commissions have been instrumental in drawing aside the veil of secrecy in many cases and have brought the true facts to light, so it is to be hoped that with a continuation of educational and publicity work by all we may be able to obtain a fair degree of justice.

The political powers that be in New York State have recently been threatening to emulate the Province of Ontario by developing and distributing electric power in certain favored localities at absurdly low rates. The Association's Public Policy Committee has been very active in combating this scheme and it has aroused more or less general opposition from the public, none of which, however, has been unified or well directed. Recent publications have laid bare many of the sore spots in the methods of Ontario's Hydro-Electric Power Commission, but none of the derogatory facts can hope to obtain the wide publicity that the announcement of low rates for power by a governmental body can, unfortunate as this may be.

In connection with public sentiment and the vital relation it bears to our industry, your chairman cannot resist calling attention once more to the evil results, past, present and future, of over-capitalization. As electricity has become more and more of a necessity, we can not afford to ignore this point, and many corporations (including others than those dealing in electrical energy) have felt the force of public opinion and have found it difficult or impossible to sustain their side of the argument when the amount of their outstanding securities is shown to be out of all proportion to the fair replacement value of the properties, even with the most liberal depreciation allowances. Over-capitalization is not only a matter affecting the older companies organized before the present awakening of public sentiment and the establishment of Public Service Commission or in States where such Commissions do not exist, but is unfortunately seen even to-day in the consolidation of separate properties under holding com-

panies, a method which is becoming very popular. Prospective economies in management and the incidental risks of the undertaking must be given full weight, but even then it will be found in far too many cases that the amount of securities issued or authorized is excessive. In many instances "stock watering," as it affects the rates charged for our product will be found to equalize itself on account of competition with other sources of power, and most of the progressive State Commissions recognize this fact by distinguishing sharply between value and cost of service in determining fair rates to be charged. There is danger in any attempt to ignore or minimize the effects of over-capitalization because of the certainty of ultimate commission control in those States now without it and a lack of uniformity as to the "fair rate of return" which the various controlling bodies will allow.

The occasional failure of an expensive dam emphasizes the importance of the most careful and painstaking engineering work both before and during their construction. Many companies and individuals having more or less experience in designing and building small dams argue that larger ones can be constructed by the same methods they have always used. In the majority of hydro-electric plants the dam is the all-important feature as regards continuous operation; but when the failure of the dam may mean possible loss of life and property there is only one proper course to pursue—obtain the most expert advice available and do not tie yourselves up necessarily to one man or firm, but obtain corroborative reports from several sources. The expense, in the long run, will be insignificant as compared with even a partial failure.

Your chairman desires to make a strong appeal at this time for more earnest and active support of the Hydro-Electric and Power Transmission Section by the Class B and E members of the parent body. By support I mean the contribution of cold cash in the shape of Section dues as distinguished from the large and enthusiastic attendance at the sessions of the Section during the conventions. Since the time when the Section was formed three years ago, and increasingly so, it has been generally agreed that it will fill a place hitherto unoccupied by any other body. Much of the work of vast usefulness to be accomplished by the officers and committees requires financial aid—more than

can be given by the parent body—and the Section dues are the only means available at present for obtaining the necessary funds. The attendance at the last two conventions warrants the conclusion that a large number of Class B and E members are interested in the Section's activities, but the results of the Membership Committee's work would indicate that comparatively few of those who show so much interest once a year are willing to contribute even the nominal dues. It is my strong recommendation that some change be made that will necessitate the payment of Section dues to obtain either admission to the meetings of the Section or the distribution of the various papers and reports presented.

THE CHAIRMAN: The chair will be glad now to entertain a motion to refer the address to a committee for consideration and report at a later session.

MR. DAVID B. RUSHMORE, Schenectady: Mr. Chairman, I so move.

(The motion was duly seconded and carried.)

THE CHAIRMAN: This program, as most of you know, has been planned by the chairman and other officers of the National Section in co-operation with the officers of the Association. I am sure it is appropriate and it is a pleasure to me now to turn the meeting over to Mr. Ryerson.

THE CHAIRMAN: The next number on the program is the Report of the Committee on Membership, Mr. R. J. McClelland, of New York, chairman.

MR. R. J. MCCLELLAND, New York City: The very brief report of the Committee on Membership will appear in the proper place, and the only thing I want to say is that each and every one of you will be handed this morning an application blank, and I hope that you will all make a special effort to give us that support which your Chairman has referred to in his address.

Another thing I want to comment upon is that the Membership Committee has divided the country up into districts, and a vice-chairman has been appointed for each district, such as the Pacific Coast, the Northwest, the Central West, and the Eastern part of the country; and probably each one of you will receive some literature, to which you need not reply if you are already a member.

REPORT OF THE COMMITTEE ON MEMBERSHIP

The increase in membership of the Section has been so small during the past year that the committee will confine the report to the work that has been done during the past few months.

It was late in December when this work was undertaken and during the next two months we were able to persuade Mr. E. M. Gilbert of the Central Colorado Power Co., Denver; Mr. G. H. Boggs, of the Pacific Gas & Electric Co., San Francisco, and Mr. D. F. McGee of the Pacific Power & Light Co., Portland, to act as Vice-Chairmen, covering their territories. We could not find in existence a suitable list of hydro-electric transmission companies, so we confined our efforts to the preparation of such a list before starting an active campaign for membership. With the assistance of the Secretary's office, we succeeded in obtaining the names of about 450 hydro-electric power companies, each having a capacity of 1000 hp. or more. Out of this list, less than 200 were members of the Association, and less than 50 were represented in the Hydro-Electric and Power Transmission Section. This list has been divided among the members of the Committee, and we have sent out a personal letter to the active manager of each company soliciting membership in both the Association and the Hydro-Electric Section. With these letters we have sent printed matter, which explains fully the work the Association has done in the past, and what we wish to accomplish in the future. Our secretary has also sent to each non-member company volume III of the report of the last annual Convention which contains the papers and discussions of the technical sessions. This will serve better than anything else to give the companies an idea of the work covered by the Hydro-Electric Section.

Of course this is only the beginning, and to make the work effective, the Committee feels that this should be followed up by again writing to those who do not respond.

Respectfully submitted,

R. J. McClelland, *Chairman*
G. H. Boggs
E. M. Gilbert
D. F. McGee

MR. RUSHMORE: May I ask just as a matter of information how far that part of the organization of the Section has gone, and how many accredited members we now have?

MR. McCLELLAND: About 65 members.

THE CHAIRMAN: Any further remarks? If there are none, we will pass on to the next number, a paper entitled "The Failure of Conservation to Conserve," by Mr. E. H. Thomas, managing editor of the Seattle *Post Intelligencer*. Mr. Thomas not being here, the paper will be read by Mr. L. H. Conklin, Secretary of the Section.

THE FAILURE OF CONSERVATION TO CONSERVE

Few policies designed for the public good have been abused like that of conservation of our natural resources.

Wise exponents of this policy repeat with tiresome monotony that smug definition of conservation: "the wise use without waste of our natural resources." This definition makes an appeal to the ordinary prudent, thrifty person. The ordinary person, however, has had neither the time nor the opportunity to investigate our conservation policies and to learn whether or not they are fulfilling the promise implied; whether or not as a result of conservation practises we are getting a "wise use" or any "use" of our natural resources.

A bureau in Washington, D. C., called the Bureau of Forestry of the Department of Agriculture, in so far as conservation affects us in any large or vital way, has had supervision and practical administrative charge of the forests, water power and minerals in and on the public domain. This is literally true despite the fact that water-power and public lands are under the jurisdiction of the Department of the Interior. This function of the forest service, supervision of resources on the public domain other than growing and protecting forests, has been usurped by the extension of the forests to cover these resources —water-power, coal beds, etc.—regardless of forest conditions. None have disputed its rights. The Bureau of Forestry has been upheld by executive order. It was the pet branch of government under the administration of Col. Roosevelt, and during those seven years it grew arrogant and tyrannical.

If mineral or water-power rights are desired, the forest service has been the agency which obstructed the way. This bureau has always been ready to assume that no locator or claimant within the boundaries of any of the national forests, where most of our undeveloped minerals and water-powers exist, came there with honest intent, and as a consequence every step of the proceedings under which water-power, mineral or agricultural rights on national forests can be granted is persistently contested by the forest service.

There could be but one result of such policies, the result that now obtains—stagnation.

The national forests of this country cover an area of more than 190,000,000 acres, an empire larger than Germany. Within these forests are millions of acres of non-forested lands, some 30,000,000 acres of this class, according to the Forest Service reports. As the service regards 4000 feet of timber per acre as timber lands, and as timber of that class in the western forests is worthless, the actual area of non-forested lands is really about 45,000,000 acres. There should be room for some development here, but what are the conditions?

Hostility to development has marked our conservation policies. This hostility has gone so far as to denounce all who favored development as the foes of conservation. No resource can be touched without a long and expensive contest in which the claimant or locator is either worn out or impoverished by the delays.

Development in progress within the areas of our national forests is to-day less than it was when the present forest service was created in 1897. Instead of progress in a part of this country greater than the empire of Germany, there has actually been retrogression.

Instead of use without waste we have followed a policy of waste without use. Let me illustrate.

The report of Chief Forester Henry L. Graves, contained in the last annual report of the Secretary of Agriculture, estimates the new growth on the national forests at six billion board-feet per year. This is the crop, growing and decaying like wheat. To refuse to harvest it is to lose it. Yet this is just what the forest service has done. At six billion per year the crop for the seven-year period preceding 1912 was forty-two billion feet. What was the harvest? The reports show that the service in that same time, 1905 to 1912, cut 1,901,532,000, or less than 5 per cent of the crop.

Is this use without waste or is it waste without use?

Conservationists have had much to say about coal and water-power, but when we invade that field and begin to investigate we find the same proportions of waste and use. The chief coal beds of the Pacific Coast are in Washington, British Columbia and Alaska. The coal of lowest quality is in the State of Wash-

ington and of highest is in Alaska. California has been producing enormous quantities of fuel oil which has practically displaced coal for all steaming purposes over the entire Coast country. This condition has forced up the price of domestic coal, because of the small proportion of lump and the large proportion of the fine coal heretofore marketed as steam coal, but for which little or no market exists at present.

In 1906 the existing coal land laws were suspended through the influence with the Executive of the Forestry Bureau. The pretext for this act was the unfounded charge that some mythical interests were about to steal Alaska, and that abrogation of laws, which to this day have not been repealed, was the only method by which the alleged larceny could be stopped. Out of this has grown the Alaska issue with all its storm and stress, and present stringent coal conditions over the entire Coast.

Now what are the real facts and what have been the results of bureau abrogation of laws enacted by Congress?

The known area of Alaska's coal lands is 21,000,000 acres. Prospectors discovered these coal areas and gave them to the world. In all this vast empire 1100 prospectors staked and filed claims on the modest total of only 32,000 acres for which they paid to the government $320,000. The government appreciated the work of these men and the hardships they endured so highly that it has refused them the land, kept the money they have paid in, and is now engaged in trying to send many of the claimants to the penitentiary.

Up to 1907 Alaska was gaining population. Since that time it has been losing. The reason for this is the refusal of the Federal authorities to permit development. In 1907 the Alaska Syndicate perfected negotiations by which it could enter the coal fields and mine and market the coal. This syndicate owned some copper mines, it was building a railroad and operated a line of steamships. It has $20,000,000 invested and would have put a total of $50,000,000 into the development of that region if it had not been for the assault made upon it.

A contract to mine coal was made directly with a group of locators who had staked 5 per cent of the Bering River field, and the basis of this agreement was a coal-selling contract by which the Alaska Syndicate was to deliver a large tonnage monthly to the Grand Trunk Pacific Railroad, a Canadian corporation.

This sales contract, the coal needed for coke with which to establish a smelting industry in Alaska, the steam coal used for its ships and local Alaska consumption, would have furnished the tonnage needed to make it possible for the syndicate to build a branch railroad into the coal fields.

All the elements of a great industrial development were at hand. The coal was the key. By refusing to grant titles under any existing laws all plans were upset, however, and Alaska to-day is a land of buried hopes when it could have been and should, be a great and prosperous community. Its coal for household fuel and for every industry is imported, and this with 21,000,000 acres of coal fields untouched and undeveloped awaiting some sort of government action, no one knows what.

Not less stupid has been the conservation of our water-powers. It can also be said that nowhere in the realm of conservation could a wise use of a natural resource have been productive of so much good.

Water-power can be wasted only by a failure to utilize it. Power from steam is generated at the expense of the world's fuel supply. Every pound of coal consumed is gone forever. It can never be replaced. Water-power can be used over and over again, as often as the required head can be furnished along the course of a stream; and then over and over again along this entire course as long as the processes of evaporation and precipitation keep the forces moving. This means that just as long as streams flow on this globe water-powers will be inexhaustible.

Water-power will be here in the natural course of events long after coal beds have ceased to exist. To use this water-power now is to prolong the life of our coal resources. The more water-power we harness the more coal we have left in the ground for the needs of the future. To use this water-power is to make use of a present wasted, although inexhaustible energy, and to use it is to save the nation's coal. This use would be conservation. Its non-use is profligacy pure and simple.

Are we conserving either coal or water-power by our present national policy with respect to this use, or should I say non-use?

In an article printed in *Pearson's Magazine,* last January, I touched upon the lack of development of water-power on the public domain. In reply to this in the May issue of the same magazine Mr. Gifford Pinchot denied the charge, but analysis of his denial shows it to be only an evasion.

Just before the Hon. Walter L. Fisher, Secretary of the Interior and a conservationist, went out of office, he said, in speaking of water-power and its development on the public domain: "The regulations now demanded are so prejudicial to power investments that they (the investors) are not going on the public domain. These disadvantages are conceded but no remedial legislation is in sight."

A short time ago Mr. Daniel W. Adams, an assistant forester, a practical lumberman and a former engineer with long years of service in railroad construction, filed charges of waste and inefficiency against the forest service. He did this only after a vain effort to secure needed reforms within the service. In his bill of particulars Mr. Adams discusses water-power as follows: "The water-powers of the national forests are at present the most important resource of the country, and as time goes on will, in my judgment, predominate over all others. The present development of this important resource is handicapped by regulations which by their nature forbid its utilization."

Here are two conservationists who have had occasion to study conditions and who know whereof they speak, who were in different departments of the government, and who agree perfectly on the reason for the non-utilization of this resource.

Mr. Pinchot's position is entirely different. He has found monopoly in the domain of power development and he would rather have power waste its energy forever than that monopoly should rear its hated hydra-head anywhere. In replying to me Mr. Pinchot ignores the simple fact that I was discussing development within and on the national forests which cover more than one fourth of the total area of the State of Washington. He charges that in this State "two corporations have already secured 70 per cent (nearly three quarters) of all the water-power yet developed." He remarks that "comment is unnecessary."

Let us see if comment is unnecessary.

It is variously estimated that the States of Washington and Oregon have a possible hydro-electrical development all the way from 8,000,000 to 25,000,000 horse power. The amount developed thus far is about 4 per cent of the total available, using the lesser figure. If the two corporations "control" 70 per cent of 4 per cent of the total "yet developed," these concerns "control" between

them 2.8 per cent out of a possible 100 per cent. Comment may be unnecessary, but my comment is that this is surely a fat "monopoly."

However, Mr. Pinchot can be mistaken in his figures as well as in his deductions. In this instance he is mistaken in both.

Mr. Pinchot says: "This same powerful group" (The General Electric Co.) "controls 55 per cent of the water-power in the State of Washington in which two corporations have secured 70 per cent of all the water-power yet developed."

Let us now examine his figures.

All power sites held in this State by power concerns under private ownership have been developed. The total hydro-electrical energy now available in the States of Oregon and Washington is 311,000 developed horse power. No two companies control 70 per cent of this, however, but three companies wholly unrelated and at widely separated points, the Portland, Seattle and Spokane regions, non-competitive because of their remoteness from each other, have developed less than 60 per cent of the total, to be exact 181,173 out of 311,000 horse power. The Seattle municipal plant has 27,000 horse power and that of Tacoma 14,000, a total of 41,000. The Inland Empire railroad has a developed project of 20,000 and the Pacific Power & Light Co. 13,267 horse power. Although the national forests of Washington State are rich in water-power, two small projects only developing an aggregate of 12,000 horse power are on the public domain. One of these has abandoned further development and has purchased private rights because of the opposition of the reclamation service to any extension of power development by the impounding of the waters of Wenatchee Lake.

If only 311,000 horse power have been developed out of a possible 8,000,000, how does Mr. Pinchot arrive at the conclusion, which he states as a fact, that the General Electric "controls 55 per cent of the water power of Washington State?" If there are at least 8,000,000 horse power, and only 311,000, or less than 4 per cent are developed, how does he arrive at the conclusion that a monopoly exists?

Analyzing Mr. Pinchot's contention we have found that the smallest estimate made of available power, developed and undeveloped, is 8,000,000 horse power. The developed energy is 311,000 horse power, or less than 4 per cent of the total. This

is in the hands of six companies and two municipalities, a condition rather different from that pictured by Mr. Pinchot when he said "55 per cent of the water-power in Washington is controlled" by the General Electric Co., and, "two corporations have succeeded in securing 70 per cent of all the water-power yet developed."

If, however, some one really has a monopoly of water-power on Puget Sound how has it worked? This is the test after all.

Before any hydro-electrical project has been developed in this region electric current sold here for as high as 20 cents a kilowatt-hour. Consumers pay a 6-cent maximum to-day. Seattle's local power, light and traction corporation is manufacturing more current than can be consumed under present demands. Last year this company delivered and used in Seattle alone 365,-500,000 horse power hours of electrical energy. It takes 3.64 pounds of Washington coal to generate one horse power of energy. It is therefore evident that this company's development —none of it on the public domain—is saving 650,000 tons of coal per annum, and the total development of the two States nearly 3,000,000 tons, which, with the freight added, is worth more than $8,000,000.

There is a chance here for some conservation, but the real conservationists, after all, are the men Mr. Pinchot denounces as monopolists and power grabbers. They are saving the coal for future generations, and reducing the price of electricity to present consumers; but these so-called monopolists have been forced to make huge investments to acquire private power sites while those on the public domain remain unused and unoccupied.

The reason, and the only reason, for this is that stated by former Secretary Fisher in putting this situation up to Congress, that "the regulations now demanded are so prejudicial to power investors that they (the investors) are not going on the public domain."

When it is considered that the national forests are greater in aggregate area than all Germany, and that their administration has produced wasted crops, idle resources and a constantly growing deficit which has mounted to nearly $20,000,000 since 1905, the conclusion that conservation has not conserved is inevitable.

Conservation is desirable. No one wants to see our resources wasted by profligate use; nor should we go to the other extreme,

as we have done, of wasting them through non-use. One is as bad as the other. It is time for this country to place the administration of the public domain on a business basis, which can be done by employing practical business men to carry this work on instead of the theorists and politicians who have brought conservation into disrepute, and made it odious to that section of the country which suffers most from the stagnation of idle and unprofitable wildernesses.

DISCUSSION

MR. RUSHMORE: Mr. Chairman, it might seem rather unwise for an organization, such as our own, to allow a paper of this kind to go without any discussion into our Proceedings, where it becomes a matter of public record. It is fair to say that others would assume it to be in entire agreement with the sentiment of the organization, and of the individuals making up the organization.

What I shall have to say is not so much in discussion of the very interesting facts brought out here, as somewhat in explanation of the whole situation such as it appears to me, speaking entirely as an individual.

In all our developments of the last 15 or 20 years we have met a large number of problems not heretofore encountered, and it has been very difficult for the government, for the corporations, and for the individuals, to be able to see at once the best solution for some of these. There has therefore been noted in a great many fields a period of inactivity while public discussion was taking place and the people were working around to a just and sensible solution of these different problems. This is especially true of the water power development, a matter which by the people as a whole has not been clearly understood; and a very large part of the action of government officials has been that of people who were not clearly conversant with the facts of the problem at first hand.

There has, I think, been no suggestion or no feeling on the part of any one that this attitude of the government officials was not taken with entirely honest motives. That a period of education has been required was perhaps unavoidable. Just how the best results can be obtained in this field and how in other fields,

is something demanding the very serious consideration of this organization as individuals and as a whole.

I happen to have seen at rather close hand the activity in Albany with regard to the development in New York State of which our chairman spoke, and in which I was very much impressed with the difference between the public policy idea of itself, and the idea of it held by the reading public as expressed in the editorials of the newspapers. It means that the people as a whole, or the National Electric Light Association, is very much out of touch with the individuals in the State, and that the subject is very little appreciated.

The condition in the Province of Ontario has been brought out in a number of different ways, and a very powerful presentation has been made of the facts in connection with a point of view not entirely favorable to the scheme. The activity at Albany and throughout New York State on the part of the Public Policy Committee of this organization was very much misunderstood, and aroused a strong antagonistic feeling. I speak of this very plainly, because it is a fact, and the organization might just as well understand it. There appears before the individuals in this organization, before the Hydro-Electric Section and before the organization as a whole, a very great necessity in the immediate future of getting more closely in touch with public opinion and of educating it.

When we speak of the Government, it ought to mean that we are speaking of ourselves, but very unfortunately it does not. There is a great slip in efficiency between the intentions of the people at home and the acts of our representatives, a large part of the responsibility for which I think lies on ourselves; and if I were to point out the necessary path of activity on the part of this organization for the next year and indeed for the next few years, it would be in connection with the education of the public, the makers of public opinion, on whom any development has got to be based. There is no way of avoiding it that I can see. We have got to have public opinion with us if we are going very far.

If any one will take the time to read the editorials in the Albany newspapers during the period of consideration of this hydro-electric bill, he will understand very easily what I am speaking of. Fortunately, the public is coming slowly to understand this attitude; fortunately the government officials are becom-

ing better educated to the facts of the situation; but the future has got to be worked out, the possibilities for the development of our natural resources, the possibilities of working under federal and State regulation, which are coming without any question, have got to be worked out on the basis of an educated public opinion, which is something that I am very sure this organization will succeed in bringing about.

THE CHAIRMAN: Is there to be any further discussion on Mr. Thomas's paper? There seems to be none and we will pass to the next number, the Report of the Committee on Progress, Mr. T. C. Martin, Secretary.

REPORT OF THE COMMITTEE ON PROGRESS

GENERAL SURVEY AND POLITICAL ASPECTS

If one feature more than any other could be said to arrest the gaze of the observer in the central-station field to-day, it would be that of the consolidation into one system of numerous small plants in a given territory, requiring the application to ordinary central-station operation of the principles and practises that hitherto have applied to pure power transmission systems. We were wont, only a few years ago, to think of central stations and of power-transmission systems as things apart. To-day, so swift is the march of events and improvement in our field, we find the two arts overlapping, blended, merged, and even confused, so that one can readily imagine the necessity of entering upon a new régime which will be that of harmonization. Such a period should mean much to the nation as a whole, for the revolution is all predicated upon the conservation and utilization of hitherto wasted resources of power, upon the greater economy possible in dealing with our existing equipment, and upon cheaper, better service to the public. It is a period that will bring much scrapping of material and men, though the latter have the privilege denied to inert machinery of adjusting themselves with new capacity of usefulness to new conditions. We shall learn in such a period what our real resources of energy are. During the recent frightful hullabaloo and racket over "conservation" the man in the street has been induced to think that every "water power," big or little, developed or undeveloped, is a Golconda of inexhaustible wealth, which has either been seized by predatory interests or which he must so protect that nobody can ever seize it. The truth will emerge clearly during this period on which we are now entering that water powers, as such, are of no use to anybody; that their development is a business as risky as mine prospecting and often as unprofitable; that enormous sums of money have been lost in trying to utilize such powers; and that the keynote of our industry in all this work is not that of rapacity, but of courage. It could almost be asserted that as far as we have gone, all the savings and capital invested in

hydro-electric development would have earned a much larger profit in any other branch of industry, and that whatever success may later attend our efforts, the public will ever remain, overwhelmingly, the beneficiary.

Questions of water-power control and regulation have been largely dominating in National and State politics during the past year, and this Report must refer briefly to such matters, although they will receive attention elsewhere in the work of this Section. A few utterances and some data may be quoted in this connection, and the first place must be given to the report of the Secretary of the Interior, Mr. Walter L. Fisher, of Chicago, which was sent to Congress by President Taft in December, 1912. It embodies the formulation of an idea or principle that is not unlikely to endure through an administration elected with different political ideals, as to how far the central Government shall go in affairs more particularly affecting the States and regions within them. The report said:

"There is no more important subject now pending before Congress and the country than the adoption of a definite and comprehensive water-power policy, both with regard to streams in the public domain and navigable streams not in the public domain. During the past year the subject has received much attention in Congress and elsewhere. The hearings before the National Waterways Commission were especially important and resulted in a unanimous report* which marks at least a definite step forward toward a constructive water-power policy. Bills have been introduced providing for the definite adoption of such a policy with respect to public lands. The passage of two bills by Congress, authorizing dams in certain navigable streams, and the discussions over these bills and over the forceful messages in which they were vetoed have clearly pointed out the necessity for amendment of the General Dam Act and have suggested the amendments which would be appropriate.

"When it became apparent that Congress was not likely to act with respect to water-power sites in the public domain, a series of conferences was arranged between the representatives of the Department of Agriculture and the Department of the Interior for the purpose of drafting a comprehensive revision of the regulations of these two departments, with respect to per-

*Senate Document No. 469. Sixty-second Congress, second session.

mits for water-power development in the national forests and in the public domain generally. The revised regulations were put into effect by the Department of the Interior on August 24, 1912, so that their effect might be carefully considered by those who are interested in water-power development. On November 18, 1912, a largely attended conference, with representatives of important water-power interests and of the State conservation, water and railroad Commissioners of California, was held in the office of the Secretary of the Interior. This was for the purpose of discussing the relations between the State and National Governments with respect to water power, and especially of considering such modifications in the laws and regulations as might be suggested in order to co-ordinate the functions of the Nation and the States and make the regulations, whether State or National, sufficiently liberal to encourage vigorous development and at the same time to protect adequately the public interests. The conference demonstrated the feasibility of effective co-operation for the reconciliation or adjustment of the different interests, State and National, public and private. Many helpful suggestions were made, which are now under consideration.

"The fundamental purpose of a rightly considered water-power policy is the encouragement and stimulation of the development and use of this great natural resource for the benefit of the public and along the lines which will protect and promote the public interest. Its object is development, but development for the benefit of the public. The first public interest is, that the water power shall be developed and utilized, but some forms of development and utilization are obviously better calculated to promote the public interest than are other forms. It is therefore essential that we should determine what form of development will best promote the public interest.

"So far as the Government itself does not undertake the development of water power it is necessary and desirable that we shall offer to those private interests which do undertake its development, a sufficient opportunity for profit and a sufficient protection of their investment to secure the largest measure of development for which there is a present market or for which a market can profitably be created. It must be equally apparent, however, that to the extent to which we offer an unnecessary inducement we are depriving the community of the very

benefits upon which the present theories of industrial society depend.

"Above all, we must make certain that those who receive special privileges connected with water-power development shall, in fact, proceed by appropriate degrees and within appropriate times to develop the available water power to its highest capacity, having due regard to the possibilities of marketing the product. We must make certain that the electric energy thus created shall be made available to the community in appropriate ways at appropriate prices. If it is not to be used for the benefit of the community but is to be devoted directly to the private purposes and personal advantages of the permittee, some method must be found by which the public will receive its share of the profit which the permittee may make over and above that which is a necessary and reasonable inducement for his investment.

"The theory of our present law in these particulars appears to be that the only way in which the public interest can properly be protected is by providing that the permit may be revoked at any time by the official who grants it. To-day, however, the revocable feature of the existing law is a serious and unjustifiable obstacle to the development and utilization of one of the nation's greatest natural resources. It should be stricken out of the law, but it should be stricken out only if there are inserted in its place statutory provisions which will define, or authorize the appropriate executive agency to define, by regulations, the conditions and limitations upon which the permit is issued and for a breach of which it shall be canceled.

"It would seem to be axiomatic that where any governmental agency, whether State or Federal, owns or controls a natural resource, that agency should take such steps and adopt such policies as will insure that this natural resource is being utilized for the benefit of the community. If the particular agency, State or Federal, is called upon to expend moneys for the protection or improvement of the resource and the resource itself can, without detriment to the community, be made to produce revenues out of which such expenditures can be paid, this course should be adopted. The proposition thus laid down seems to be conceded, reluctantly in some cases but freely in others, by those who are interested in water-power development. As a rule also they concede further, that if water power is being devel-

oped and used directly by the permittee for its own financial profit and not as a public utility, the particular governmental agency issuing the permit can and should require the payment of such substantial compensation as the facts in any given case may warrant.

"Upon the other hand, however, they vigorously contend that much, if not most, of the water-power development upon navigable streams and upon the public domain is, in fact, in the nature of a public utility, in that it is devoted to the generation of electric current which is sold by the permittee for general consumption by the public for light, heat or power. They now state frankly that this development should be treated as a regulated public monopoly. Some of them contend that for this reason no compensation whatever should be exacted by the government which grants the permit, but on the other hand, those private interests whose representatives are really candid are preparing to admit that public regulation of these utilities is, generally speaking, not yet efficient, and that to the extent to which it fails to be efficient the government is justified in exacting compensation. They admit, further, that for the purpose of keeping control of the situation and upon broad general principles of public policy the government is justified in imposing a nominal compensation, even in cases where public regulation appears to be reasonably effective, and that provision for periodic readjustment of this compensation will be a useful check in securing such efficient regulation. Indeed, the only controversy of importance appears to be whether the Federal Government or the States shall control the granting of water-power permits and shall collect the compensation.

"So far as concerns water-power concessions upon streams which are not navigable, the Federal Government is directly concerned to-day only where the application is for the use of some portion of the federal domain. The important question is whether the Federal Government should retain its control over such power sites and upon what conditions the concessions shall be issued. The suggestion is made frequently by those who are in one way or another representing either present or future investment in water-power development, that such power sites and their control should be turned over to the respective States in which they are situated. It is suggested that in some way or

other a failure to do this is a usurpation of Federal power and an unfair discrimination against the Western States. It is interesting, however, to note that the ordinary citizens of these States are not at all concerned over federal usurpation or unjust treatment. They recognize that the Federal Government has full legal power to dispose of the public domain as wise policy may direct. They do not fear federal usurpation, but seek federal co-operation in supplementing State and local powers, so that the natural resources shall be utilized for the public benefit primarily of the locality in which these resources are situated, and thus ultimately for the benefit of the nation as a whole. They suspect that the real purpose of those who urge the turning over of the federal domain to the States is, that they may escape the longer and the stronger arm of the Federal Government and may take advantage of the more limited resources and governmental facilities of the individual States.

"There is no real conflict between the Nation and the States upon this subject. In fact, there can be no real solution of these aspects of the problem until the interest and the functions of the Nation and the States are co-ordinated and they are working together for the same essential ends. In general, all of the streams which are susceptible of water-power development are also of great importance for domestic use, for irrigation or for navigation. All of them depend to some degree upon protection and aid of some kind and from some source for one or more of these uses. Increasingly, that source tends to be the Nation and not the States.

"Theoretically, the States can develop and protect the streams and the watersheds of the streams within their respective borders, and if these streams are interstate in character the States affected can unite in plans and expenditures for their joint protection and development. Practically, however, the tendency is increasingly in the direction of federal action upon such matters. Some of the individual States are developing effective policies of water conservation, but it is the Federal Government after all which is called upon to make the chief expenditures for the development of navigation and for the protection of the forest cover around the sources and along the watersheds of both navigable and non-navigable streams. It is the Federal Government which will be asked to build the reservoirs in which to im-

pound the flood waters at their source, so that devastation may be prevented and the stream flow be made regular and beneficent. It is the Federal Government which has established and is maintaining the forest reserves, by withdrawing appropriate areas on the public domain and purchasing other areas in the Appalachian and other mountains of the Eastern States. The States which are jointly interested in the disposition and development of interstate waters not only do not co-operate with each other but are, in fact, antagonistic. No better illustration of this can be found than in the present attitude of State officials and some citizens of Colorado toward the utilization of the waters of the Rio Grande for the irrigation project in Texas and New Mexico, authorized by Congress partly for the benefit of these States, but largely in settlement of an international controversy with Mexico.

"If, then, the Nation is to perform these important functions, if it is to make these expenditures, if it is to be the arbiter and harmonizer of conflicting State interests, there would seem to be every reason why the Nation should retain the fullest measure of control necessary or appropriate to enable it to perform these functions effectively.

"It is true that much of the hydro-electric energy developed under Federal permit will be sold to local communities and their inhabitants for general lighting, heating and power purposes, and that the local communities affected are therefore vitally concerned in the character of the service rendered by the permittee and in the charges for this service. The improvement of long-distance transmission will tend to change this local interest into an interest interstate in character, and this change will lead to the necessary assertion of the federal power over interstate commerce, as has been the case in the field of railroad enterprise. Until that time comes, and except as it does come, it should be a fundamental principle of federal water-power policy to relegate to the States and their delegated agencies, whether such agencies be the local municipalities or the public-utility commissions, the important function of regulating the service and the rates of hydro-electric public utilities. It should equally be a feature of federal policy to utilize the revenue derived from water-power permits solely for the purposes of water development, thus returning to the local communities, not by any nice adjustment of particular expenditures to particular receipts, but

as a general policy, the contributions which these communities may directly or indirectly make to the Federal treasury. Where the local community is efficiently regulating the rates and services of these permittees, the Federal charge should be nominal in amount, but it should be susceptible of periodic readjustment, so that official inquiry may be made into the extent to which local regulation is efficient. If for any reason such regulation is not effective and the permittee is enjoying an unconscionable profit, this profit may be diminished by appropriate increases of the Federal charge. Such a policy can in no way injuriously affect the legitimate interests of the private investor or the local community."

Upon all of which admirable survey of a rather complex problem and situation, one of the leading technical journals remarked: "What American industry wants is a cheap and bountiful power supply, a stoppage of the enormous waste which is now going on, and encouragement to legitimate enterprise for utilizing it." The case is there in a nutshell. A further expression of opinion from Secretary Fisher may be quoted as important, seeing it embodies views that seem to control governmental attitude and action even under the newer administrative conditions. In a speech before the American Forestry Association at Washington, last January Mr. Fisher said the opponents of the conservation movement were devoting themselves chiefly to the accusation that the conservationists represent a purely negative principle and that the policy of the conservation movement is to withdraw from the fields of activity the national and natural resources and to prevent their effective and prompt development. In denying this accusation, the speaker said that the water powers of the country have been tied up, to its great disadvantage, because while the fuel resources are destroyed in their use the water power that is developed is perpetual and continuous, and its use is the most living and vital example of conservation. It is therefore to the interest of the country and its citizens, Secretary Fisher said, to urge and to secure the adoption of a policy which will permit these resources to be used as promptly and as fully as possible. The reason why so little has been accomplished, he thought, was not the inherent difficulty of the situation, but the obstacles which have been intentionally thrown in the way of that policy by people seeking to discredit the movement. It

happened that in March, 1911, by a rider attached to an appropriation bill, a provision was inserted which gave the head of any department having utilization of public lands and reservations the right, under rules and regulations prescribed by him, to grant an easement for a period not to exceed 50 years, for electric transmission lines and for telegraph and telephone lines. At the end of the rider a provision was added that those who already had revocable permits for a particular transmission line could obtain grants upon the same terms and conditions as were prescribed for others. Seizing upon this rider as the first and only opportunity, the Secretary of the Interior put into effect certain rules and regulations to give the constructive policy something of an impetus. These regulations, according to Secretary Fisher, went farther than it was thought necessary and wise to go, but the extreme view was adopted and the regulations were sent out to all the power interests in the United States, notice being given them at the same time of a conference at which the Secretary of the Interior would be glad to listen to suggestions for modifications.

One of the particular interests represented at that conference was the Great Falls Power Co., which asked nothing from the Federal Government and needed nothing from the Federal Government, so far as the power site of itself was concerned, but needed a right-of-way over public lands and national forests for its transmission lines. The company was then engaged in active negotiations with the Chicago, Milwaukee & Puget Sound Railroad system for electrification of its road through the mountain regions where water power is available. The power company had a revocable transmission-line permit to cross the public domain, but the railroad company was unwilling to make a contract with it unless a permanent permit could be obtained. The permit was accordingly granted on a 50-year basis. Secretary Fisher stated that when the power company made the contract with the railroad company the contract was submitted to the Department of the Interior, whose purpose it was to prevent, by a manipulation between two interests, an excess charge for the electricity purchased by the railroad company which would be a bar to effective rate regulation by the Interstate Commerce Commission. The great significance of this particular grant, he said, is twofold—first, in that it marks the first step toward the elec-

trification of the transcontinental railroads, and, second and in Secretary Fisher's judgment far more important, because it makes effective the sort of regulations regarding large power interests for which conservationists have contended.

Significant in this connection is the fact that the proposal of President Taft and Secretary of War Stimson that the Federal Government have control over water-power sites to the extent of imposing a "reasonable annual charge," was defeated in the U. S. Senate on February 17. The issue was fought out on the Connecticut River dam bill in which was included a provision for an annual federal tax. On the motion of Senator Bankhead, of Alabama, the provision was stricken from the bill. With that out the bill passed by a vote of 74 to 12. An amendment was made to the bill, at the suggestion of Senator Borah, making hydro-electric transmission companies having transmission lines passing from one State to another, subject to the control of the Interstate Commerce Commission and to the interstate commerce laws. Another amendment, added by Senator Jones, gives the Secretary of War the right to cancel the privileges on the Connecticut River, granted by the measure to the Connecticut River Power Co., if the company ever becomes part of an unlawful monopoly or corporation or ever enters into any contracts in restraint of trade. Notwithstanding the passage of the bill by the Senate, the Secretary of War did not yield in this shape in his belief in a Federal tax on water powers. He issued a statement, following the passage of the bill, voicing the opinion of the Administration and the advocates of the tax, which is in part as follows: "A dam is to be built by the Connecticut River Co. at the Enfield Rapids, on the Connecticut River. This dam will promote navigation and it will also create valuable water power for that company. I insisted that the company, as one of the conditions under which it was to obtain the Government's consent for the construction of the dam, should pay into the national treasury a share of its net profits above 8 per cent, this money to be applied by the Government toward the improvement of the navigation of the Connecticut River. The company was quite r
to do this, and the arrangement was carefully drawn up and agreed upon. The majority of the United States Senate, comprising almost all of the Democratic members, are unwilling to permit this contribution to be made to the national treasury. They

insist that this valuable privilege shall be granted to the Connecticut River Co. without any such return, and they insist upon this in face of the fact that the company is ready to pay it. I do not believe that such a position is good law or good business or good politics, and I venture the prediction that in spite of this apparent rebuff the day when these valuable water powers will be given away for nothing is over." It is apparent that the old delusion of "giving away" water powers still obtains amongst some fairly intelligent people from whom better things might be expected.

The Governors of a good many of the States do not at all see eye to eye with the National Government on these questions of conservation, in which respect, as intimated by the incident just noted, they are supported by many other distinguished and influential citizens. At the meeting of the National Electrical Contractors' Association in Denver last summer, for example, Governor Shafroth asserted that the recent cessation in hydro-electric development, as well as the stagnation in land development and coal-mine development, was due to the Federal policy of conservation for the central government rather than by the State. This the Governor regarded as discriminating in favor of older States where water powers, coal mines, gas and oil wells were developed, unrestricted by governmental interference or taxation, thus making great manufacturing States out of Massachusetts, Pennsylvania and Ohio. In Colorado the heavy expenses of State government, roads, schools, etc., must be borne, together with an added tax for the development of its natural resources. Fifteen million acres, or a territory as large as New York State, belonged to the Federal Government and paid nothing toward State expenses. Since by the State enabling act, water and all natural rights and properties belonged to the people of the State, the government makes a tax on transmission systems of about $1.00 per year per horse power transmitted. The avowed object is to prevent fraud and monopoly, but the State can and will as effectively regulate common carriers and can initiate laws if necessary. The government tax of 10 cents per ton for coal means ultimately $37,000,000 tax on the people of the State, and the transmission tax will ultimately mean $1,000,000 a year. Governor Shafroth asserted that there would be an investment of $100,000,000 in hydro-electric plants within three years if the Federal restrictions were withdrawn.

To show that such views are not individual but general and symptomatic, it may be noted that at the luncheon of the Colorado Electric Club in Denver, February 6, Governor Ammons, discussing the electrical development of his State, and referring to the undeveloped natural resources in metal mines and agriculture, urged the need for better utilizing the waters of the State, both in the mountain streams for power purposes and by the electric pumping of wells for irrigation. Such pumping, declared the Governor, often proves to be cheaper than gravity irrigation with long ditches and shallow storages, on account of the latter's limited usefulness and large losses by seepage and evaporation. Governor Ammons assailed the position of the Federal Government in exacting royalty for the use of State waters because they originate partly on government land. This policy, he declared, discriminates against Colorado by denying it ready development of its resources, although Eastern States have in the past been allowed the greatest freedom. Governor Ammons urged State control of water-power rights.

Very much the same points of conflict have been emphasized in the control and regulation of the energy from the Niagara River, and in the differing views on these subjects taken by estimable authorities. Last year a bill was introduced in the National House of Representatives controlling the diversion of water on the American side of the Niagara River and the importation of electricity from Canada. The Burton act expired by limitation on March 4, and it was proposed to take from the Federal Government the control of the diversion of water in navigable rivers and, in the Niagara Falls case, invest it in the State of New York. The treaty between Great Britain and the United States authorizes the United States to permit the diversion of not more than 20,000 cu. ft. of water per second, while the Canadian Government is empowered to authorize the diversion of not more than 36,000 cu. ft. per second. At present the diversion on the American side of the Niagara River aggregates 15,600 cu. ft. per second. The bill before Congress did not permit the diversion of any more than that amount, and whereas the Burton act permitted the importation of a maximum of 350,000 hp. from Canada, the bill limited the amount to 200,000 hp. It also made it obligatory for the generating companies to utilize the water at its maximum efficiency and stipulated that the companies

receiving permits for the transmission or delivery of electrical energy should be regulated as to rates, etc., by the Public Service Commission of the State, or where such a commission was lacking by the Governor of the State.

At the hearing on January 22, the State of New York, through its Attorney-General, claimed that after the Government had decided how much water may be diverted from the Niagara River, it was entitled to control the diversion of the water and to decide the parties to whom it should go. It was contended that while the Federal Government has a right to determine the quantity of water that may be diverted from a boundary stream in the exercise of its constitutional right to control navigation, that power is exercised pursuant to that constitutional right only for the purpose of regulating and controlling navigation and for no other. Moreover, it was asserted by the State of New York that the Federal Government has no right to say how much power shall come into the State of New York from Canada, or what shall be done with it, any more than it has the right to say how many bushels of wheat shall come in from Canada or to regulate the price or amount of imports.

The junior Senator from New York said that the State, in its sovereign capacity remains the owner of all its property, subject only to the exercise of all of those rights or provisions which the State voluntarily transfers to the Federal Government such as, for instance, to promote navigation, make treaties and provide for the common defense. The president of the New York State Conservation Commission expressed opposition to any legislation which would permit the existing generating companies to get any additional water from Niagara Falls. He said that the present policy of the State was to utilize all the undeveloped water powers for the benefit of the people generally, and to utilize whatever water is available at Niagara Falls for the generation of electricity, to be transmitted to the various municipalities and through them to the ultimate consumer at practically the cost of its development. He also maintained that true conservation presupposes the utilization of all water at its maximum efficiency.

It was brought out at the hearing that the taxes of the Niagara Falls Power Co. to the State and municipalities aggregate $3.00 per hp., while the Canadian Government charges practically $1.00 per hp. The Cataract Power & Conduit Co., which

distributes Niagara energy in Buffalo, pays the Niagara Falls Power Co. $16 per hp.-year and sells it at practically $25 per hp.-year, the difference being used to pay all the charges of transformation and transmission to Buffalo and its distribution in that city. It was pointed out that whereas the Hydro-Electric Power Commission of Ontario pays $9.40 per hp.-year for energy to the Ontario Power Co., as against the $16 charged by the Niagara Falls Power Co., the latter charge is for energy transmitted to Buffalo while the former charge is for energy delivered at the terminals of the transforming apparatus, or practically at the power house. It was said that by limiting the amount of energy that can be imported from Canada into the United States, Congress had glutted the Canadian market with cheap energy. The secretary of the Niagara Falls Power Co., stated that his company had had offered to it by the Hydro-Electric Power Commission of Ontario the same opportunity as the Ontario Power Co., and refused to sell energy at $9.40 per hp.-year, claiming that it would be unprofitable even at approximately $14 per hp.-year. He also pointed out that the Ontario Power Co. generates 17 hp. for every cubic foot of water per second that is used, whereas the Niagara Falls Power Co. is able to generate only about 11½ hp. for every cubic foot of water per second used.

The counsel for the New York State Conservation Commission asked the committee on foreign affairs to consider the three following propositions: First, to render available for use all of the water granted by the treaty; second, if Congress had the power to do so, to compel the companies to submit themselves to the jurisdiction of the controlling powers of the State of New York; third, to have Congress give that controlling power in New York an opportunity to say what shall be done and what price shall be given for the energy after it comes into the State. The member of the committee on foreign affairs from Texas pointed out that, as a matter of conservation, the companies which are already developed at Niagara Falls and have the machinery and equipment were in a very much better position to give cheap energy to the people than others that had no equipment whatever.

All of which is very interesting. The bill as finally reported gave the Secretary of War authority to regulate the diversion of

the water at Niagara Falls, but left to the State Public Service Commission the right to control the rates charged for the electrical energy developed. No change was made in the provisions of the Burton act limiting the amount of water to be diverted on the American side to 15,600 cu-ft. per second. By final legislation in Congress on March 4, the Niagara power companies were allowed to use 4000 cu-ft. per second up to the full 20,000 allowed by the international treaty.

Another interesting case within the corners of this problem is right here in Chicago. Secretary of War Stimson made a decision this year, refusing the additional diversion of water from Lake Michigan for the Chicago Drainage Canal sought by the trustees of the Sanitary District of Chicago. The Secretary of War held that the Drainage Canal had never received the direct sanction of Congress. He held that the withdrawal of 10,000 cu-ft. a second would interfere with the navigable capacity of the Great Lakes and their connecting rivers. In 1899 the Secretary of War permitted the Sanitary District to take 5000 cu. ft. of water per second from Lake Michigan. About $70,000,000 has been spent in building the canal and the works connected with it. A water power was created by the flow of water and a 28,000-kw. hydroelectric plant has been built and is in operation at Lockport, Ill., a large portion of the electrical energy being used for the purpose of lighting the streets of Chicago. In relation to this water-power development, Secretary Stimson said that for every horse power realized at Lockport 4 hp. could be produced at Niagara, where the natural conditions are much more favorable. On the part of the City of Chicago, it is urged that the present canal represents the development of a national policy for uniting the waters of Lake Michigan and the Illinois River which goes back to 1827.

Before passing on from this particular phase of the subject, reference may be made to the paper read at the October Chicago convention of the American Electric Railway Association by Mr. James E. Hewes, of H. M. Byllesby & Co., on "Advantages to Communities Through the Development of Water Powers," in which the concrete suggestion was put forth for a national commission of experts to solve waterway and water-power problems on a broad scale. Mr. Hewes said:

"Our first duty in this matter is to see that honest business men and properly qualified engineers form a commission, prop-

erly paid for its services, to determine a broad plan for the development of river navigation and water power, wherever power can be developed advantageously and where a dam must be used for navigation.

"A dam used for navigation improvement is usually not the dam best adapted for power purposes, because the head is low, and if such a dam were used in power development high water would cause great fluctuations in capacity.

"In such problems the commission I have mentioned could determine whether it be feasible to build a high dam instead of a low dam; also whether the additional expense is warranted by the Government, or if corporations should pay it because of the development of power for their use.

"Such a commission would solve a problem that no one administration has yet solved. This is a problem that ought not to be an administrative problem. It is unfair to put the burden on an administration, but the administration that creates such a commission as I have outlined will have done the biggest thing yet done by any administration. A commission that would accomplish the control of floods in the Mississippi Valley and its tributaries and improve the navigation of the river, would be doing a bigger thing for posterity than the digging of the Panama Canal or anything else that has ever been done by any single government for its people."

Mr. Hewes pointed out the enormous loss of life and property in the United States due to floods, and said that the first great benefit of water-power development is the prevention of floods. The present Governmental policy, he declared, is "saving at the spigot and wasting at the bung-hole." The Government should begin down-stream and work up. Continuing, he said: "The Mississippi Valley has many water-power sites where development would mean prevention of floods, cheap navigation and fair income to corporations that could be induced to co-operate with the Government in the joint development of water power and the improvement of navigation." Every dam not used for the development of electrical energy means just so much loss of income to the community. At the present time "it is an almost insurmountable proposition to obtain Government consent to build a dam, unless provision is made for navigation, such as

the building of locks at rapids over which even an Indian has never paddled his canoe."

The economic importance of water-power development in saving coal was pointed out by Mr. Hewes. "Thanks to high-potential electrical transmission, I dare say it is possible to-day to cover the entire area of the United States with a network of high-tension lines connecting together, with efficient distribution, all of the water powers capable of development in the United States."

Navigable waterways mean a saving in transportation. "These are the big things which we should conserve to the people and hand down to posterity—navigable rivers, cheaper transportation and developed water power, the coal remaining to heat the bodies of our descendants." The sun, in lifting water, is the greatest pumping plant in the universe, and the author believes that this is about the only way in which its rays can be used as a large source of power. It is the one great perpetual motion.

SOME STATE OWNERSHIP PLANS

It is certainly evident that some of the States take very seriously the idea that all the power and all the sources of power are theirs; yet other States go further and are willing both to check and hamper private development while committing the taxpayers to vast schemes of utilization, of more or less uncertain value and of very doubtful profitableness. The Legislature of Washington had before it this winter, for example, a bill which provided that the waters or streams in the State necessary for irrigation could not be used for the generation of electricity to be sold in other States; which strikes one as equivalent to the proposition that all the wheat or coal raised in any given State must there be consumed. The measure was directed against the Northwestern Electric Co. proposing to utilize the Klickitat River, and deliver its energy chiefly in Portland, Ore. It seems obvious that there would still in the end be just as much water for irrigation.

The disposition of 250,000 hydro-electric horse power, the possible development of the streams of eastern Nebraska, is the aim of an investigation made this winter by the Nebraska Legislature into the feasibility of a plan by which the State could issue

bonds, develop the power and sell the energy to the cities of Omaha, Lincoln, Sioux City and other places along the Missouri River. Under existing laws the Commonwealth has no authority to enter upon this field of work, but advocates of State ownership are urging that the Legislature enact the necessary laws and undertake the development. A bill with that aim in view was introduced in the Legislature, and a committee has been engaged in making the investigation. Nebraska does not produce a pound of coal or a gallon of oil, and the development of its water powers is of vital interest. There is a fall of some 5000 ft. between its western and eastern boundary, and its big rivers are capable of developing large quantities of electricity. Kountze Brothers, bankers, New York, the Moore syndicate of Detroit, and the Babcock-Doherty interests have grants for developing more than 100,000 hp. on the Platte River, and the sites are all within transmitting distance of Omaha. Governor Aldrich, however, is opposed to State development, and Prof. G. E. Condra, director of the State conservation work, agrees with him. According to Prof. Condra, the State should grant the power sites to private parties, but should retain supervision over the development. He says that this is the best practical means of securing development without exploitation and sacrifice of the public interest. Probably all of us, and most others who have studied these subjects, will be inclined to agree with them.

A good deal of this agitation has undoubtedly sprung from the astounding claims made as to the results and success of the Hydro-Electric Power Commission of Ontario, Canada, to whose enterprises reference has been made in previous Reports of Progress to this Association. New York State, as will be presently shown, has suffered greatly from the acceptance at their face value of the statements put forward as to the wonderful operations of this body in a neighboring Province. The evil might have spread, but in the meantime a corrective has been applied with most salutary results, already seen, in the book: "An Expensive Experiment," by Mr. Reginald Pelham Bolton. It is a close and searching analysis of all the conditions involved in the operations of the Canadian Commission, which without any real generating plant of its own, has been enabled through a splendid private development at the Falls of Niagara to get energy at as low a figure as $9.40 per hp. (and other small sources bringing the average of

33,000 hp. up to $11.14) to supply a large number of municipalities in the Province at relatively low rates. When it is stated that the rates are based on a mere maximum demand, it will be seen that the small community, unable to keep down its peak and flatten the curve is not getting exactly what it was promised; and in the meantime the burden of indebtedness assumed and borne by the towns and cities is enormous. One of these places shows as low as 19 per cent use of the power contracted for, and excluding Toronto, which made a good bargain but still shows a large and growing specific deficit of its own, the use in September, 1912, of all the other municipalities was only 71 per cent of their contracted totals. This, of course, should improve in time, but Canada may plausibly be assumed to have a bad reaction ahead of it after the enormous boom of recent years; and the burdens must still be borne. The fact remains that a transmission system capable of utilizing 60,000 hp. with estimates of nearly 115,000 hp. contracts has got only as far as 33,000 hp., and that several communities by legislative permission cut their contracts 40 per cent. With over $4,000,000 invested by it alone, the Province Commission up to the end of 1912, is clearly shown really not able to pay its way, has no generating plant of its own and no steam standby reserve, and is discriminating in rates in a way no private corporation ever dared to attempt. The share of the capital cost of the transmission line involved in connecting the city of London, Ont., to Niagara amounts to $256 per hp. used. As Mr. Bolton points out, a good steam power plant could be constructed for one-third of that, and good coal is purchasable in London at $3.00 per ton. Mr. Bolton sums up his general review of the expenditures and burdens imposed by this latest sad venture of the State in business, as follows: "Added to all of this is the loss which the community as a whole has suffered by depreciation or stagnation of the value of the securities of private corporations and some loss of returns upon the funds invested therein by citizens of the Province; and the loss of the taxes which the communities could have secured upon the increased values accompanying an increased business of these corporations. If all these elements could be ascertained and their capitalized value determined, it would result undoubtedly in figures which added to the public expenditures, would make the resulting service afforded through the Hydro-Electric

Commission one of the most expensive speculations in which the people of a State have ever become involved." Allowing for errors of judgment it may be asserted that a system which suspends its sinking fund, treats the element of depreciation as negligible and charges various costs of operation, administration and maintenance to capital account, does not "put it over" on private hydro-electric enterprises which may also have found the minus qualities of profit in the business but which at least bear the losses themselves and do not throw them on the whole body politic.

All this leads up to the interesting situation in New York State, where along some of the lines of the dismal Canadian experiment, it has been proposed since last this Section met to plunge the Empire State into a vast hydro-electric development and transmission scheme under the auspices and control of the State Conservation Commission. It would be hard to find anything much more spectacular and glamorous in our field. The literature of the Commission some people would be inclined to describe as having been written by an optimistic lunatic living in a millennial utopia—with its promises of cutting everybody's electrical bills in half, furnishing electricity practically for nothing in the remotest wilds of the Adirondacks, and giving superabundant employment to all the people in the State—"and then some." How such extraordinary documents could ever get out bearing the name of the great State of New York is a mystery and hardly short of a scandal.

At the last session of the New York Legislature a bill was introduced by Senator Bayne providing for a state-wide scheme of hydro-electric development and high-tension transmission under State ownership and operation, for the purpose of selling electrical energy to municipalities and the public. The proposed act was introduced as an amendment to Chapter 647 of the Laws of 1911, entitled "An act relating to the conservation of land, forests, waters, parks, hydraulic power, fish and game, constituting Chapter 65 of the Consolidated Laws." It was proposed to repeal Article VI thereof and enact a new article in its place covering the general project just mentioned. The provisions of the new article stipulated the general powers and duties of the State Conservation Commission, which would be charged with the administration of the scheme. The character of service to

municipal corporations, contracts for distribution, purchase or construction of distribution plants, construction of transmission lines, the letting of construction contracts, appropriation of property and other allied matters were covered in the fourteen sections of the act.

The joint legislative committee named to investigate the State's water-power resources submitted its report, recommending a plan for conservation and utilization diametrically opposite to that of the Conservation Commission. The committee declared that it would be impossible for the State of New York to develop a sufficient amount of hydraulic power to make any appreciable impression on the power demands of the State. It investigated the plan of the Hydro-Electric Power Commission of Ontario and reported that, in its opinion, measured by economic and business standards, the plan could not be a success. The committee pointed out that there is within the State a daily hydraulic consumption of over 2,000,000 hp. and that to deliver this at the point of utilization would require over 8,000,000 hp. at the penstock. It found that there is undeveloped within the State only 1,196,800 hp. of which 262,700 hp. is actually owned by the State, the rest being claimed by private owners. The committee declared, regarding the Hydro-Electric Power Commission of Ontario, that it has never developed any water power but has acted merely in the capacity of middleman in the mechandising of electrical energy; that it furnishes electricity to the municipalities below cost; that if the same methods were applied as are employed in business transactions of a similar nature there would be an annual loss of at least $432,170, and that in addition to this loss to the Province the local distribution systems of the municipalities would also show a loss. It is claimed that the municipal system of Toronto showed a net loss to June 30, 1912, of $268,984.

This disposal of a state-wide visionary project narrowed the scheme down to a utilization of the prospective development of water power on the New York State barge canal at the Crescent and Vischer's Ferry dams, for the benefit of Albany and adjacent territory, a scheme to which the State Legislature committed itself while this Report was going through the press. But it is not unwise here to put on record as practical prophecy the illuminating analysis of the project made by the Public Policy Commit-

tee of this Association through its able chairman, Mr. Arthur Williams. The document is one to which in future years the Association and Section will be able to "point with pride" for its scientific linking of conservation with the conservatism that protects what is already conserved.

This analysis points out that, although the Commission's engineers propose developing from 12,000 to 36,000 hp., an actual survey of the water conditions show that 12,000 hp. would be available only 175 days of the year, owing to periodic low water and excessive flow. For a maximum yearly capacity the supply can be relied upon for only 6000 hp., which is equivalent to less than 4000 hp. delivered at the consumers' premises.

For this initial development the Commission proposed to spend $625,000. Placing interest at 4 per cent, sinking fund at 1 per cent, depreciation at 6 per cent and loss of taxes at 1.5 per cent, the total annual fixed charge reaches 12.5 per cent. The annual cost of the development omitting labor, repairs and supplies, therefore becomes $78,000, or more than $19 for each hp-year available to the customers. These figures include only cost of transmission and omit the distribution plant in cities to be supplied.

Although costing $19 per hp-year, it is proposed to sell this hydro-electric energy in the capital district for $7 or $7.50 per hp-year. In addition to this, as a member of the Conservation Commission has publicly advocated, it is the intention to build a large steam plant to supplement the water power. For this steam plant an investment of at least a million dollars would be required. Including distribution expenses the fixed charge per hp-year at once amounts to $40, including nothing for labor, supplies, repairs or steam-plant fuel.

The barge canal was built entirely from State funds, the presentation goes on to state, so that therefore it is less than equitable that the facilities obtained at such large cost should be appropriated by and devoted to cheapening the power service of a comparatively few, thus placing local manufacturers in the favored district in a position of controlling advantage. The Committee points out that since the dams belong to the public, any income derived therefrom should be devoted to the entire State, for the reduction of general taxation, which means that

the privileges should be sold publicly, and without any favoritism, to the highest bidder.

Enormous sums of money are already invested in the State's public utility corporations, whose services generally are adequate and their prices reasonable. More than $1,200,000,000 of private capital is now invested in the utilities of the State, returning about $18,000,000 to the general welfare of the commonwealth. In conclusion the Committee points out that for the $625,000 appropriation asked it is proposed to develop hardly more power in the capital district than is required by one of the larger single office buildings in New York City. This would be developed at a loss to the entire citizenship, in credit upon their taxes and in additional loss through increased taxes to make up deficiencies in the proposed service, while there would be set in motion a policy which cannot but be most destructive to the State's great vested interests.

Our Public Policy Committee recommended that, instead of the proposed measure, legislation be enacted if necessary to permit the sale of this and other State water powers (or at least this power as an experiment) at public auction, to the highest bidder, or their lease upon the most favorable terms, using as a minimum those adopted by the national government, and with the understanding that the operator, whoever he may be, shall be subject to the lawful control of the Public Service Commission.

The rest of this incident will be history, as sad and squalid as that of the Ontario experiment.

ONE OR TWO POLE LINE DECISIONS

In view of the wide areas of country covered by transmission circuits, and the complex nature of many of the new questions and problems introduced by working at high potentials, it is a matter for felicitation that in reality so few disputes and difficulties have arisen from the clashing of different interests, each with a legitimate business to develop and protect, each with good reasons for what it believes to be a sound policy to pursue. One of the chief of the troubles has been due to the disturbances caused on telephone circuits by induction from neighboring high-voltage circuits; while there has been the incidental "hazard" due to the exposure of low-tension circuits in general to our

high-tension, high-energy transmission systems. Obvious principles in the treatment of these problems have gradually emerged, thanks largely to the work done through conference by the Overhead Line Construction Committee of the N. E. L. A., but disputes have continued, and in such a progressive industry controversies may always arise. Herewith are noted one or two pole line decisions of more than usual interest in this respect.

One case is that of the Bell telephone interests in Illinois against the Springfield and Northeastern Traction Co., as to the right to overbuild an existing telephone or telegraph line with a parallel high-tension transmission circuit on the same right of way. The case was decided for the plaintiff in the chancery division of the Circuit Court of Logan County last year, although the dispute arose in 1907. At that time the traction company, one of the members making up the Illinois Traction System, commenced to build its road through Lincoln, forming part of a continuous route from Peoria, Ill., to Springfield, Ill., and points south. The single-phase traction system was employed, with catenary construction supported from span wires and a trolley-wire pressure of 3300 volts at 25 cycles. On one of the lines of poles, at the street curb, there was carried a 33,000-volt, 3-phase transmission circuit and sundry low-tension wires for signaling and communicating purposes. At the southern outskirts of the city there was a transformer substation, similar to a number of others, receiving energy over the main transmission circuit from Peoria or Riverton, Ill., or both. For a distance of about 700 ft. in one of the principal streets the line of 65-ft. wooden poles supporting both the span wires and the high-tension circuit was set in line with the poles of the telephone company, so that the 33,000-volt line was about 14 ft. above the telephone wires and parallel to them. The traction company's poles were of chestnut set 7 ft. in the ground, surrounded by 10 in. of concrete; the butt diameter was from 12 in. to 15 in., and the top was 7 in. to 8 in. Each pole carried three 2-in. by 4-in. fir cross-arms, one 10-ft. arm for the high-tension circuit and two shorter arms for the signal and telephone circuits. The transmission wire was No. 2 B. & S. gauge bare copper, tied to pin-type porcelain insulators with three and a half turns of No. 6 B. & S. gauge wire. The cross-arm braces were held to the arm by bolts and to the pole by a lag screw. In several places the poles of the traction com-

pany were in contact with the wires of the telephone company. On September 23, 1907, the traction company's construction in the vicinity was completed. During the middle of 1909, however, the traction company abandoned the high-tension system in dispute and substituted everywhere the good old-fashioned 600-volt direct-current system.

Judge Harris in his opinion filed on August 8, described both complainant and defendant as public-service corporations differing only in prior authority and occupation of street. The opinion stated that the construction of the telephone line was such that the respondent could not complain of it, and from all the evidence of all the witnesses no protective device could be used in telephone construction which would safeguard it against a pressure of 33,000 volts or anything like it. After considering the question of the Court's jurisdiction, the opinion goes on to state that "so far as concerns the respondent the complainant was occupying Chicago Street between Broadway and Clinton Street, not with any exclusive franchise, not with any amount of space to be measured and set off to it, but with the right as against the respondent to occupy so much of the street as was necessary for the successful operation of its business." A little further on the opinion says: "The thing to be guarded against by respondent in the construction of its line under the law, as I understand it, is such an interference as will prevent the practical operation of the telephone system."

The remainder of the opinion dealt with the question of whether the respondent had so interfered with the rights of the complainant, considering alone the transmission line, that an injunction should be issued. Again the Court stated that the respondent's duty was to use every reasonable safeguard to prevent accidents. Moreover, the Court regarded the evidence as showing beyond dispute that with any of the construction described in the evidence accidents occur from such high-tension lines. Telephone, telegraph, electric light and power lines are not immune to decay or destruction caused by the elements. The evidence preponderated also on the proposition, in the Court's judgment, that high-tension lines crossing over, under or paralleling low-tension lines introduce an element of danger which otherwise does not exist, demanding extra precautions in the way of shorter spans, extra cross-arms and the use of screens

or cradles. The judge recognized that cradles impose an extra burden on the line and tend to cause other trouble, but regarded them as necessary and pointed out that they were in use even by the respondent. The opinion then concluded as follows: "Therefore I find from the evidence that the construction of the transmission line of respondent upon Chicago Street between Broadway and Clinton Street in the City of Lincoln is not the best, most approved and modern construction. While practicable, it was not necessary to the successful operation of the railroad to be so located, but located by election of respondent under lawful authority and is a right belonging to respondent which the Court will not set aside or order removed provided the respondent recognizes the rights belonging to complainant, to be by respondent protected, provided and equipped with the safeguard to minimize the dangerous and hazardous conditions that now exist. Injunction will be granted as prayed for in the bill, except as modified by these conclusions."

In like manner a decision was handed down about the same time by a Court in Iowa in favor of the Mills County Telephone Co. and the Iowa Telephone Co., which were decreed to be lawful prior occupants of the highway, as against a high-tension system coming in later which, it was held, interfered with and endangered the telephone lines and the telephone users. The high-tension circuits were built above and parallel to the telephone lines at three different locations for a total distance of 1 1/3 miles. The defendants, a construction company, were ordered to remove at their cost the telephone lines to the other side of the road without interruption of the service. The decision then set forth that the high-tension line crosses the telephone lines at eleven locations and ordered that the defendents should reconstruct their line so as to provide for and maintain:

(1) "A vertical clearance over plaintiffs' lines of not less than eight (8) feet. But where practical in the judgment of plaintiff's division engineer, plaintiffs will consent to defendants doing the work of lowering plaintiff's wires to aid in obtaining said clearance. But in no case shall plaintiffs' wires be placed lower than 18 ft. above crown of adjacent highway.

(2) "All high-tension crossings to be above telephone lines at all points.

(3) "Poles supporting the crossing span and the adjoining span on each side of said crossing span shall, where practical, be in a straight alignment.

(4) "Poles supporting crossing spans shall be side-guyed in both directions at right angles with high-tension line wherever practicable and be head-guyed away from the crossing span.

(5) "All anchors shall be iron at least ½ in. in diameter; all guy wires to be of 5/16-in. stranded steel wire.

(6) "All poles supporting crossing spans shall be double-armed—arms to be provided with metal plate and ground wire sufficient to carry the short-circuit capacity of the high-tension current on said lines.

(7) "The wire in crossing spans shall be stranded, equal in size to a No. 4 B. & S. gauge wire. Or 5/16-in. stranded wire may be used at defendants' option, and said wires shall be dead-ended on insulators on the cross-arms supporting crossing spans.

(8) "All poles supporting crossing spans shall be sound and of sufficient size and strength to sustain ½ in. of sleet per wire with wind blowing 50 miles per hour. The parties to this proceeding shall inspect all crossing poles and any rejected as insufficient by two engineers of plaintiffs shall be replaced by defendants within 60 days by sound poles not less than 7 in. in diameter at top and 36 in. in circumference at a point 6 ft. from butt of pole.

(9) "All new pins in crossing spans shall be of selected locust.

(10) "All of the changes herein specified to be made by defendants at their own expense and in a first-class workmanlike manner, defendants furnishing all labor and material at their own expense."

The plaintiffs also received judgment against the defendants for the costs of the case.

A FEW ENGINEERING ASPECTS OF PROGRESS

There is little need for this Committee to go into engineering details of progress, as these are covered in the admirable reports presented by a number of special committees on various branches of the subject as noted in the program. Perhaps a few references

and citations may be made with benefit, and no better introduction could be asked for than the recent comments, on the situation by President Mershon, of the American Institute of Electrical Engineers: "The highest transmission voltage put into practical operation during the last year is 140,000 volts. This is the voltage now regularly employed on the lines of the Au Sable Electric Company in Michigan. The highest projected voltage is 150,000 volts, for which the lines of the Pacific Light & Power Corporation are being constructed. Although the value of voltage, in common with other considerations affecting the transmission line, is usually fixed by economic considerations, there is one element in connection with all transmission lines, whether high voltage or low voltage, not ordinarily considered as being strictly subject to economic limitations alone. This is the matter of interruptions due to lightning. Strictly speaking, this question is also determined by economics. Because if we chose to spend a sufficient amount of money on an installation it would be possible to make it immune to atmospheric disturbances. To do this in the case of a long high-voltage transmission would mean such an enormous first cost as to be entirely prohibitive. So it might be considered, in view of the enormous cost involved, that these costs themselves compel the classing of the problem as a physical one instead of an economic one. That is, it may be considered that such drawbacks as still exist in the art of transmission due to atmospheric disturbances are drawbacks which from practical considerations must necessarily be overcome, not by an enormous increase in first cost, but by some solution having to do more directly with physical conditions—by some solution having mainly to do with the working out of a problem in the arrangement of transmission lines, or the insulation of transmission lines, or both—and which is, therefore, more immediately physical in its nature and does not greatly involve the relation between cost and the result obtained.

"While this physical problem of procuring for transmission lines practical immunity against atmospheric disturbances involves in some measure the arrangement and disposition of the lines, the present tendency is to consider it more a problem of insulation and its accessories. This is shown in the investigations that are now beginning to be actively taken up with relation to the effect on insulators of such electrostatic stresses as may be

met as the result of lightning; in the study that is being made as to the relative effectiveness of insulators when subjected to voltages at ordinary commercial frequencies and to the same voltages at frequencies approximating those which we are led to believe exist in the case of many lightning disturbances.

"It has long been known that insulators which would flash over at ordinary frequencies, rather than puncture, are often punctured on a transmission line by lightning disturbances without any evidence of accompanying flash-over. In other words, there seems to be no question that there is some very considerable difference in the condition which exists when an insulator is, on the one hand, subjected to a given voltage at a commercial frequency and when, on the other hand, it is subjected to the same voltage at an enormously greater frequency. Or, to put the matter in a little more exact language, the behavior of insulators when subjected to a difference of potential whose rate of change, or steepness of wave front, approximates those which are met with in commercial work, is quite different from the behavior of the same insulator when subjected to a difference of potential whose rate of change is enormously greater than that normally impressed upon the line.

"The results obtained so far seem to point to the possibility of obtaining insulators which will meet that condition usually considered most desirable for enabling them to withstand lightning disturbances; that is, that of always withstanding the tendency to puncture to such an extent as will force the abnormal voltage to flash over the insulator instead of going through it. If this condition of affairs could always be insured, we might have a line practically immune to every condition save that of malicious interference. Because, if we could be sure that the insulator would always flash over and never puncture, it is comparatively easy, at relatively small additional expense, to make such provision as will insure the insulator against harm by the power arc following such flash-over.

"The direction in which the greatest progress to-day can be made in the art of high-voltage power transmission is that indicated above. Undoubtedly the greatest desideratum at the present time is an insulator which will always flash over, rather than puncture, under any voltage to which it may be subjected, and will not be damaged by a flash-over. As a secondary matter, it

is desirable that the power arc following a flash-over should not interrupt the service rendered by the transmission system, but as previously mentioned, means are now available by which such interruption can be almost entirely insured against. The need, therefore, is only for an insulator which will never puncture and which will not be injured by the power arc following a flash-over during such period of time as may elapse from the time the power arc starts to the end of the very short period of time during which the auxiliary apparatus referred to has had an opportunity to suppress the arc.

"The tendency is more and more toward installing high-voltage apparatus outdoors. Undoubtedly the time will come when all high voltage apparatus whatsoever will be so installed. There is no good reason, either logical or financial, for going to the expense of bringing a high-voltage terminal through the metallic case of a transformer or switch of which it is a part and then going to a similar expense to bring the same terminal out through the wall or roof of the building housing the apparatus. A terminal built to withstand the weather might just as well be put on the metallic tank in the first place and the apparatus placed out of doors, thus saving not only the insulating bushing but practically all of the building as well, since with such an arrangement no protection is necessary save that for switchboard panels and operators."

In the way of increasing efficiency note may be made of tests reported within the last month or two, on a pair of 6000 hp. water turbines. Such turbines seldom show efficiencies exceeding 85 per cent, and at anything but the most advantageous gate opening 80 per cent is not an uncommon figure. The wheels in this test operated under a head of 49 ft. They are large vertical-shaft turbines and therefore obtain some advantage in the matter of friction. The performance shown by the wheels was remarkable. The maximum efficiency rose to between 93 and 94 per cent and remained above 90 per cent from about 80 per cent load up to full load, after which it dropped off rapidly. The rise in efficiency toward this maximum was extremely steady and the wheels passed 80 per cent efficiency at half load. Great care seems to have been taken in the test to eliminate sources of error in the weir measurement. The results obtained seem to be attributable to very careful design and manufacture helped out by skill in

placing the wheels. In arranging the draft tubes particular care was taken to avoid as far as possible the eddies which are known to have a serious effect on turbine efficiency. The importance of these minor details is shown in the slight but very plain difference observable in the tests of two similar turbines. The one that gave the lower efficiency discharged slightly to one side of the tailrace, producing some eddies, and these seem to be apparent to the extent of 1 or 2 per cent in the efficiencies obtained.

The resort to larger and larger water-driven units is illustrated this year in the 19,000 hp. hydro-generators installed in the Pirahy station to supply Rio de Janeiro. Two units of this capacity have been installed, the generators being of American Westinghouse make and the turbines and governors of Escher-Wyss construction from Switzerland. The installation is an interesting one. The power station, which has been in operation since 1907, is situated on the River Lages about 50 miles from Rio. Three-phase energy is generated at 6000 volts and 50 cycles, the e.m.f. being stepped up to 80,000 volts for transmission. The equipment in operation prior to the installation of the two 19,000-hp. units consisted of six 8700-hp. impulse-wheel units and three 200-kw. exciter sets, two of the latter being operated by Pelton wheels and one being motor-driven.

The River Lages has a drainage area of 193 sq. miles with an average rainfall of 59 in. a year. The river descends in a series of rapids, and falls nearly 1000 ft. in a distance of only a few kilometers. A dam at the top of the falls forms a reservoir, with an average level of 1323 ft. above the sea. The power station is built 308 ft. above the sea level, so that the gross head available for the turbines is 1015 ft.

Water was conveyed from the dam to the power house by pipe lines in two sections, consisting of two upper low-pressure lines, one receiver pipe and six lower high-pressure lines. At the time the new units were installed two high-pressure pipe lines were added. The diameter of the low-pressure pipes is 8 ft. and that of the high-pressure pipes 3 ft. The lines are fitted with relief pipes. The high-pressure pipes for the new turbines are divided into three sections having diameters of 56 in., 54 in. and 52 in. respectively. Relief pipes 400 ft. long are installed. The gross head available at the turbines is 1015 ft., which is reduced by pipe friction losses to an equivalent of 925 ft.

The power plant of the Mississippi River Power Company now in course of construction at Keokuk, Ia., and to be described during this Convention by Mr. Hugh L. Cooper, will ultimately contain thirty 10,000-hp. generating units. At the maximum head of 39 ft. the output will be approximately 14,000 hp. per unit. The water-wheels are of the single-runner type operating at 57.7 rev. per min. They are directly connected to vertical, low-speed generators. The thrust bearings are a combination roller and oil-pressure bearing. As the total weight of the unit which each of these bearings has to support is 275 tons, the importance of the oil supply is very apparent. The oil is pumped to the bearings by means of triplex pressure pumps made by the Goulds Manufacturing Co., of Seneca Falls, N. Y. It is supplied at a pressure of 250 lb. per sq. in., which is sufficient to lift the unit so that it floats on the oil and relieves the rollers of the load. The pumps have 6½-in. cylinders and 8-in. stroke. They are operated by chain drive from a line shafting.

As compared with these water-power units, the steam units still hold the first place in magnitude and capacity, as well as voltage. The largest unit in the world was ordered while this Report was in preparation by the Commonwealth Edison Co., of Chicago, from the General Electric Co. The unit will be a 30,000-kw. horizontal turbo-generator to be placed in the Northwest generating station. It will be delivered about July 1, 1914. The exciter will be installed on the shaft of the machine, and the length of the unit over all will be 60.5 ft. The width will be 18 ft. 4 in. and the height 14 ft. The generator will be a 9000-volt, 25-cycle, 3-phase machine. It is to be operated at a speed of 1500 rev. per min. and is designed for an output of 1925 amp. per phase. The turbine will be operated at a steam pressure of 230 lb. with a supertemperature of 200 deg. fahr. The weight of the entire unit will be about 1,000,000 lb.

We have had one instance in this country, at the Snoqualmie Falls, Wash., of a subterranean generating plant, but while it is still in successful operation, the verdict against it is shown in the later construction at the same spot, abandoning the cave idea, and placing the entire outfit above ground from forebay to tailrace, so that, to say nothing of the initial economies, everything can be seen in the light of day and can be got at swiftly. Attention has, however, been called quite recently to a similar

plant in Sweden, where a 65,000-hp. system utilizes at Mockfjord the Stop Rapids; and the cave dweller idea thus persists. The wheel chambers, blasted into the rock, have a steel lining back-filled with concrete, and are of a cylindrical shape 21.3 ft. in diameter. Four double-runner Francis turbines, each rated at 5100 hp. at 225 rev. per min., are mounted in a horizontal position at the bottom of these chambers, with the shaft centers 24 ft. above the lowest tailrace level. Two wheels discharge into the same tailrace tunnel. These tunnels are about 5000 ft. long with a 322.8 sq. ft. cross-sectional area. At a distance of 164 ft. from the turbines there are large pockets in the roof, each of about 2000 cu. yd. These pockets are interconnected and provided with vertical shafts, the object being to prevent water hammer. So far this arrangement works satisfactorily. The wall between the generator room and the wheel chamber has a minimum thickness of 18 ft. and consists mainly of the natural rock formation. The generator room is 31 ft. wide and 105 ft. long. It has an arched reinforced concrete roof. The maximum height of the room is 29.5 ft. An inclined tunnel serves as a communication between the subterranean generator room and the transformer house. In the bottom of this tunnel there are ducts for cables and fresh air. The tunnels and the shafts are lined with reinforced concrete. From the wheel chambers steel tubes, 4.26 ft. in diameter and backfilled with concrete, lead through the rock into the generator room. Through these tubes, the diameters of which have been made as small as possible in order to preserve the rock, are taken the turbine and rocker ring shafts, spaced 2.5 ft. center to center. The single rocker ring shaft is in the wheel chamber parted in two shafts placed diametrically opposite each other along the turbine.

The governors are belt-driven from the turbine shafts and all parts are mounted on the same bedplate. They are provided with hydraulically and mechanically operated hand-controlled, gate-setting devices. Small electric motors, controlled from the switchboard, are provided for synchronizing the units. The generating equipment consists of four 4500-kv-a., 6600-volt, 3-phase units operating at 225 rev. per min. and 60 cycles. They are totally inclosed and provided with intake and outlet for cooling air. The warm air, liberated from the top of the generators, rises through a vertical shaft to the pump and fan house directly above.

Line construction has necessarily received a good deal of attention during the year, as will be found from other Reports. As an example may be instanced the data from the committee on electrical transmission of the Ohio Electric Light Association, comprising information as to a number of lines operating at from 6600 to 33,000 volts in Ohio, Indiana and Kentucky. The Committee reported that the practical working radius of 2300-volt transmission is very limited, being about one mile for 25 cycles and 3700 ft. for 60 cycles, when the wire is loaded to its carrying capacity and the pressure drop is 10 per cent. The transmission-line design centers on the operating voltage. A good rule is 1000 volts per mile of line. For example, a 6-mile line would require 6000 volts. The usual spacings may be summarized as follows:

Volts	Minimum Spacing, Inches	Maximum Spacing, Inches
6,600	12	48
13,200	18	36
22,000	30	36
33,000	36	72

The greater the number of provisions against lightning the better the possibility for uninterrupted service. The aluminum-cell arrester has proved very efficient. It not only affords a path to ground for lightning but aids in removing all internal line disturbances. However, this arrester has a serious disadvantage in the necessity for charging it each day, thus making its efficacy dependent on the operator. The multi-gap arrester also relieves surges and is found very effective up to 13,200 volts. Ground wire is best placed at the top of the line structure so that it has a shade angle of 45 deg. to the outside conductors. It may be a 3/8-in. stranded galvanized plow steel or bimetallic wire. Such a ground wire is good for mechanical reasons, for it ties the tops of the structures together, thereby adding strength to the construction. The ideal construction comprises ground wires at the highest points of the poles and aluminum-cell arresters at both ends of the line and in the center. It would seem that what the art needs is some dividing line at which "distribution" ends and "transmission" begins; but such boundaries are probably like the "movable feasts" of the Church, and it is certain that distribution voltages are rising all the time under our newer conditions.

The increasing scarcity of timber and consequent rise in price have compelled engineers to look for substitutes, so that for many purposes, steel and concrete have long since replaced wood. For pole lines, however, not only for low-tension telegraph and telephone work, but in transmission service, wood is still in quite extensive use. The principal objection is the higher cost of the newer materials, and it hardly seems likely that this can be overcome for the present, especially if we get scientific reforesting. Another objection found to concrete poles is their increased weight as compared with either wood or steel; a solid concrete pole weighing perhaps on the average three times as much as a wooden one of the same strength; and a hollow pole about twice as much. Data are still accumulating on these points and others as to strain and durability, and will be welcomed. Meantime there is a very notable increase in steel towers and in concrete construction.

For this reason it may perhaps be worth while to note that during the past year the Central Colorado Power Co. has adopted a wooden transmission tower construction for a new 70-mile line at 100,000 volts. Each tower comprises one 45-ft. and one 40-ft. pole, which are set into the ground to a depth of 5 ft. 6 in. At the ground line the poles are separated by a distance of 17 ft. 6 in., and converge to a distance of 11 ft. at a level 35 ft. above the ground. The cross-arm is formed of a pair of 4-in. 5¼-lb. steel channels bolted together at their ends and inclosing the poles as a bow-spring. Although pinned to the poles by through-bolts the spring pressure of these deflected channels is sufficient to grip the cross-arm securely in position. A 10-in. spacing block is inserted at the mid-point of the bow, and the channels are braced to the poles with 4-ft. knee pieces. These towers are spaced at 500-ft. intervals throughout the 70-mile line. The arrangement of suspension insulators used places all 3-phase wires in the same plane. While such disposition is susceptible of slight theoretical disadvantages, the arrangement has the great practical advantage of permitting any wire to be reached and worked upon without danger of contact with the others. The ground wire is carried at a distance of nearly 8 ft. from the nearest conductor. At each pole a ground tap is run down under staples and wrapped in a spiral about the pole butt to provide a permanent earth connection. The Central Colorado Co. has used a construction similar to this in some of

its 13,000-volt lines, where the bow-spring cross-arms are formed of two 6-in. by 6-in. hardwood members. With this construction spans as long as 1100 ft. have been used.

Another special modification used on these 13,000-volt lines where it is desirable to avoid guying against the fierce winds that prevail in the region has been an A-frame arrangement. Two 30-ft. poles are erected 30 ft. apart, at an angle of 30 deg. with the perpendicular, forming an equilateral triangle. The frame is linked and braced by 5/8-in. bolts extending through plate cross-pieces. At distances 6 ft. down each pole, measured from the apex of the frame, provision is made for attaching strain insulators, the jumpers between spans passing around the poles. The top wire is then attached to the frame cross-piece, while the lower conductors clear the ground by 20 ft. This construction has been used in a mountainous country for a distance of nearly 3 miles, the maximum of the 47 spans being 1100 ft.

As to line conductors, the greater use abroad or outside this country of aluminum continues, without any apparent explanation except that under the old tariff, copper has held its advantage. Under ordinary conditions an aluminum conductor at American prices is just a few per cent cheaper than the equivalent copper conductor, so little cheaper in fact that the extra cost of supports and of stringing the aluminum equals the saving. In Europe and in Canada the ordinary quotations of aluminum are about the same pound for pound as copper at the base price, and for hard-drawn wire a saving in the use of aluminum figures out at from 35 to 40 per cent. The duty has been kept just high enough to block importations. As a result of this the transmission line outside of American territory is more than likely to be constructed of aluminum, while inside our tariff, copper has to be the chief reliance. The new tariff if it goes into effect may possibly change these conditions somewhat. It has been pointed out that in the case of long-distance transmission at very high pressures the extra cost of the insulator makes very long spans more economical, and then the cost of the insulators and towers is so great as to make the cost of the conductors a comparatively small proportion of the total cost. This, combined with the fact that the towers must be some 10 per cent higher with aluminum cables in consequence of their greater sag, and wider on account of the greater spacing to prevent touching when swinging in a

gale, results in reducing the saving effected by the use of aluminum from 4 to 6 per cent, as shown by the official publications of the Ontario Hydro-Electric Commission. A careful analysis of the figures of cost shows that, in the case of the main line to Toronto, consisting of two 3-phase circuits each comprising three No. 4-0 B. & S. cables, the six cabies cost $1,450 per mile as compared with $2050 per mile for copper cables (copper wire at 16 cents per pound and aluminum at 23.5 cents per pound), showing a saving of nearly 30 per cent on the cables alone. This saving was reduced to 5.6 per cent only on the total cost of the line, partly because the actual towers weighed 1.72 tons as against 1.57 tons for towers for an equivalent copper line, and partly because the cost of the cables was only 30 per cent of the total cost of the line, including erection but excluding rights-of-way.

It has been stated that one of the chief reasons for the use of aluminum in preference to copper for the above lines was the lower corona loss with aluminum conductors. At the high pressure employed, namely, 110,000 volts, the section of conductor for copper was so small as to approach the limit at which the corona loss becomes very considerable, and the 28 per cent greater diameter of the equivalent aluminum cable was, therefore, an important advantage. As the corona loss is one of the most important of the difficulties to be overcome in future lines at very high pressures, this advantage of aluminum will necessarily carry great weight. Commenting on this and the fact that there were at the time of its remarks some 30 aluminum transmission lines in the British Isles, the *Electrical World* remarked: "One of the interesting minor advantages of aluminum for the very high voltages as found on some of the Canadian lines is that owing to its larger cross-section for the same conductivity the tendency to coronal loss is somewhat reduced. At the present time there are about 30 transmission lines in Great Britain using aluminum conductors. It is instructive to note that on some of these lines the engineers have taken advantage of the light conductors to increase the span considerably beyond ordinary pole-line practise in this country. Our British friends may be conservative, but their conservatism is rampant anarchy compared with the attitude of most American engineers toward the long-span pole line. If we are lucky enough to obtain cheap aluminum in the

future, possibly the British practise may serve as a welcome source of courage. Be that as it may, it seems to be a fact that the aluminum line in foreign practise is being installed in many cases and with pretty uniform success. The old hesitancy about using a new metal came chiefly from the earlier product strung as solid wire and of dubious strength. A first-class stranded aluminum cable as manufactured to-day is entirely free from the risks once feared."

SUNDRY DEVELOPMENTS OF THE YEAR

It is interesting to note that our own Convention has been recently preceded by a special meeting of the American Institute of Electrical Engineers in Pittsburgh, to discuss the general subject of the application of electricity in mines, a subject which comes well within the sphere of this Section, although it is not less concerned to develop the production of electrical energy at the mine. At this meeting, Mr. J. S. Jenks stated that the West Penn system has now 76 coal mines on its lines with an aggregate load of 14,831 hp., and in April was connecting 10 more, with 5701 hp., making a total of 20,532 hp. He hopes soon to have 30,000 hp. of coal mining load on the company's circuits. Mr. E. D. Dreyfus stated that from personal observation he knew of over 200 coal companies using central-station and power-transmission service and believed that to be only a small percentage of the whole.

That is one aspect of development of this kind. The other is that of energy production at the mine itself for transmission. For instance, the casual reading of a magazine article a few years ago by Hon. H. J. Logan, formerly member of the Canadian Parliament for Cumberland County, Nova Scotia, was the initial step in the establishment of the pioneer electric transmission plant of the Maritime Coal, Railway & Power Co., Ltd., of Amherst, N. S., at the mouth of the celebrated Chignecto mine, located eight miles southeast of the latter city and within easy transmission distance of an important industrial and coal-bearing area. The article in question suggested the possibilities of electrical transmission from the pit mouth, crediting the scheme to Mr. Thomas A. Edison, whom Mr. Logan visited at his New Jersey home. They discussed plans for the carrying forward of the enterprise, and on July 31, 1907, service was begun to the accompaniment of

a telegram of congratulation from the great inventor and in the presence of many distinguished guests. The plant has now been in service for over five years and its success has completely demonstrated the practicability of turning the potential energy of slack or refuse screenings into electricity for sale in distant markets. The demand for its output has constantly increased, and to-day the installation is the source of electrical supply for the municipalities of Amherst, Maccan, Nappan, River Herbert, Joggins and Chignecto, operating about 60 motors with a combined rating of 900 hp. and a lighting load of about 10,000 16-cp. equivalents in the above communities. Factory machinery, a gypsum quarry, pumps, blowers, hoists, fans and other equipment are included in the motor load, and by the use of an otherwise unmarketable fuel which constitutes about 30 per cent of the mine output the plant is enabled to deliver electricity at economical prices throughout the entire district. This is a typical illustration, and a pioneer one of what is being done and is on the way. Another case is that of the Luzerne County Gas & Electric Co. at Kingston, Pa. It presents the very unusual condition of an electrical system, covering some 30 square miles of territory right in the heart of a coal-mining region, selling a great deal of electrical energy to the mines and buying coal locally at current prices. In other words, it is in effect hauling coal from the mines and delivering back electric energy to them cheaper than it can be generated at the mine mouth. A somewhat singular set of circumstances led to the unusual results noted. To begin with, the coal costs from $1.10 to $1.30 per ton, delivered. Of course, the refuse and screenings available at the mouth of the mine would be cheaper than the buckwheat used, yet it appears that, on investigating the relative economies, the saving by using the cheaper coal has been found not so great as might be anticipated. In some instances this result has been due to the scarcity of water supply at the mouth of the ordinary mine, and still more chargeable to the difficulty of utilizing very cheap fuel on a small scale. The economical burning of culm and similar fuel requires conveying apparatus on a large scale and can be best done in a plant much larger than the ordinary mine would require. Hence the plant can afford to utilize cheap coal hauled from nearby mines and then distribute electrical energy back to the mines at a profit to all concerned. The coal is hauled to the station in carts and

dumped into a large concrete coal bin, from which a motor-driven conveyor distributes it to the boiler room. It is not even burned on automatic stokers, nor are the ashes disposed of automatically, although an ash-conveying system has been installed. The operating conditions make the success of the plant in energy distribution all the more remarkable. It is at least an open question whether, even with this cheap fuel, the energy costs are not needlessly high, considering the size of the plant, by reason of its design, yet the cost of fuel per ton is so low that any difference secured by a considerably more expensive plant would be so moderate as to make the economy a questionable one until the plant has to carry a much greater load. The requirements found necessary with coal selling at $3.00 or $4.00 may prove to be uneconomical with coal at $1.25.

In a way the same conditions have developed in the zinc district of Missouri. It might seem that an electrical distribution from steam-driven generators, operating in a territory supplied with gas and extremely cheap coal, would encounter commercial difficulties of an almost insurmountable character. Even a decade ago the supposition would have been painfully true, yet to-day in regular commercial work and on a business-like basis the thing is being done, as shown in the Empire mining district, which lies in the Missouri and Kansas territory long known as the center of the lead and zinc mining industries. In that region are more than 600 mines in operation, of all sizes. This territory is now served by the Empire District Electric Co., which has in operation 9 generating stations, 19 substations, 100 miles of 33,000-volt transmission lines and an equal mileage of 2300-volt distribution circuits. It serves, besides, the running needs of a scattered community of more than 150,000 people and 165 miles of interurban railway. This service of itself is not remarkable, but that it should grow and prosper where gas can be had for 25 cents per 1000 cu. ft. and coal is somewhere about $2.00 per ton speaks volumes for the practical advantages of electric power. Mining, however, involves peculiar conditions in the use of power, and experience has shown that under the circumstances of average use the power costs in mining run abnormally high. For instance, in one case of mine pumping it was found that even with fuel gas at only 12.5 cents per 1000 cu. ft. the actual fuel cost per 1000 gal. pumped rose to 4.8 cents. When the steam pump was dis-

carded and an electric pump installed in its place the cost for the power fell to 8.3 mills per 100 gals. In addition to more than 100 pumping installations, many motor-driven air compressors are in use, with hoists and other equipment, bringing the total connected motor load up to about 25,000 hp. The load curve of the system is unusual on account of the mining service, with a long peak from 9 a. m. to 3 p. m., rising to some 11,000 hp. last summer. Building up such a business is no easy matter, for, as usual, the users of power have no exact knowledge of its real cost, yet load is steadily being secured in spite of the very low nominal cost of fuel. One exceptional feature of the practise here is the very large use of 2300-volt induction motors, all above 30-hp. being thus wound for the regular distribution voltage. Taken altogether, the system is a beautiful example of the adaptability of electrical energy in the face of cheap gas and coal.

Fuel oil utilization in long-distance electrical work is well exemplified by the Redondo plant of the Pacific Power and Light Co. to which attention has been directed in previous Reports. This station, located at Redondo Beach, 18 miles southwest of Los Angeles, is remarkable for its use of double vertical and horizontal reciprocating engine units and for the extremely high fuel economy attained in its operation. When burning fuel oil in the furnaces of its water-tube boilers, the plant produced, in a 15-day run, 252.8 kw-hr. per barrel of oil, the barrel weighing filled 334 lb. and each pound containing 18,500 lb. fahr. thermal units. This economy has been well maintained on the whole since the well known acceptance test on the station was made. The station furnishes energy for the operation of a large portion of the interurban trolley system of the Pacific Electric Railway Co. and the street-railway service of Los Angeles, in conjunction with the Kern River and other hydro-electric plants by which the Pacific Light & Power Co. supplies electricity throughout its extensive territory. The plant has now had added to it two 15,000-kw. 3-phase generators, and a total nominal equipment of 40,000 kw. in engine and turbine units is located in an area 200 ft. long by 80 ft. wide.

RECENT DEVELOPMENTS AND INSTALLATIONS

The past year has been prolific in new enterprises and developments, due in some degree to the significant shifting over of the central-station industry as a whole to the transmission basis

of producing its energy. How far this will go no one can yet see, but it certainly means larger plants, longer transmissions, and, with rational legislation and the encouragement of capital, the utilization of various natural powers still running to waste. These are undoubtedly exaggerated in the public mind in number, extent and value; but after all is said and done, the concrete residue awaiting the skill of the engineer is enormous and destined to advance this great industry to an incalculable extent. It will be interesting here to note what some of our big systems, steam and hydro, are already doing. The table below shows the outputs, peak loads and load-factors of the central stations in Chicago, New York, Philadelphia, Boston and Brooklyn for the year just closed. The Commonwealth Edison system still has the highest peak load and the largest output of the central-station systems, owing to its great railway load. The New York Edison Co. took over the load of the Third Avenue Railroad Co., approximating 28,000 kw., but too late to make any impression on the yearly output. In this connection the output of the Niagara Falls Power Co. and the Canadian Niagara Power Co., which virtually comprise a single system, the stations being operated in parallel, is of interest. The peak load on that system occurred

DATA ON LARGE GENERATING SYSTEMS

System	Peak Load in Kw	Date of Peak Load	Yearly Output in Kw-hr.	Yearly Load Factor of System Per Cent
Commonwealth Edison ..	233,000	Dec. 11	799,000,000	43-44
New York Edison*	189,726	Dec. 20	513,926,429	30.8
	210,813	Dec. 23	†619,290,064	†33.4
Philadelphia Electric‡ ...	65,489	Dec. 23	183,969,655	32
Boston Edison	60,143	Dec. 18	161,702,955	30.6
Brooklyn Edison	42,500	Dec. 17	125,770,000	33.7

*Exclusive of service to railroads.
†Including railroad load estimated for entire year.
‡Philadelphia only.

on March 8 and was 115,900 kw. The output for the year, however, was 868,392,750 kw-hr. and the load-factor of the system (ratio of yearly average to highest peak in year) was 82.29 per cent, making it in point of the output the largest system in the world. The figures, however, do not reflect natural conditions at Niagara Falls. During most of the year the output of each of the plants was rigidly limited by the restrictions of the Burton act, and during a large part of the year a part of the Buffalo load

was supplied from the plant of the Toronto Power Co. at Niagara Falls, Ont. The total output of Niagara would of course run far beyond the figures quoted.

In noting a few of the developments of the year, first place may perhaps be given to governmental work and the fact that while this Report was in press, awards were made in this country for the greater part of the material required for the construction of the Cristobal-Balboa transmission line, 48 miles long, which will be the principal feed of the system on the Isthmus for the Panama Canal. As to other conditions, notably those in the West, attention may be directed to an excellent article appearing in the *Scientific American* of April 5, 1913, on the harnessing of the public water powers. At least a part of it may be quoted here, with the data as to what has actually been done. The author, Mr. C. J. Blanchard, of the U. S. Reclamation Service, says:

"Upon the adoption by Congress of a comprehensive and practical water-power policy depends to a great extent the future development and progress of a large part of the West, and in a somewhat lesser degree of many parts of the East, South and Middle West. The time is ripe just now for an adjustment of the differences which have existed between the Federal authorities, the States and private interests, and a definite policy is looked for in the near future. Indeed, a long step in this direction was taken during the closing hours of the last administration when plans for State and Federal co-operation were formulated and the Department of the Interior in an agreement with a large power company in Montana secured recognition of its right to make certain provisions for the regulation of rates to govern the operations of this company which desired to use some of the public domain. As a result of this agreement the electrification of probably 400 miles of a transcontinental railway is practically assured and a new market for the 'white coal' of the West is provided. A precedent has been established and the bugaboo of Government regulation tying up development has been laid on the shelf for the time being. If one of the largest power companies in the West and a transcontinental railroad have found it posible to enter into an entirely satisfactory agreement with the Department of the Interior, notwithstanding the present notoriously inadequate laws, future complaints by promoters and exploiters that their plans for development are pre-

vented by departmental red tape will perhaps not be accepted with the same confidence by the public and the press. It has not always been the fault of the Department that private enterprises have been checked and halted. More often the fault has been with Congress, which while enacting laws for withdrawals and restrictions, has persistently declined to provide legislation to enable the Department to unlock the storehouse in order to permit untilization and development for the public.

"Representatives of the Departments of the Interior and Agriculture during the past year held numerous conferences which resulted in a comprehensive revision of the regulations governing the water-power permits in national forests and on the public domain generally. Later a largely attended conference was held with representative water-power interests and of the State conservation, water, and varied Commissions of California. There were discussions of the relations between the State and National governments with respect to water power and modifications in the laws and regulations in order to co-ordinate the functions of the Nation and the States. This conference was extremely illuminating in that it fully demonstrated the feasibility of effective co-operation.

"In the working out of a definite plan for the utilization of our natural resources and particularly the water powers, only one Federal bureau has been actually engaged in the engineering work of developing power. The Reclamation Service, organized in 1902 for the purpose of making habitable large areas of irrigable public lands, has constructed a number of power plants and has launched the Government in the power producing business in several localities. Originally the idea of power development was solely for the purpose of pumping water to lands above the reach of the gravity canals, but wise management decreed when there was demand for surplus power, that all such power which could be economically developed should be provided for in the construction of the plant. In this way the Government has found itself in the field as a maker and seller of electric power. It is a rather advanced step in the governmental activities, but no one has yet seriously questioned its practicability and certainly no one can gainsay its success financially. It is understood that the Government's control of these public utilities is not to be permanent, as it is contemplated in time that their operation and main-

tenance as well as the revenues will be turned over to the people who have assessed themselves to repay to the Government its investment. The Government in this connection might be regarded as in the position of a contractor who has built and is operating its plant until its owners have met their obligations to him.

"The following table shows the present condition as well as the possibilities of power development on the reclamation projects:

Project	Power Developed, Hp.	Possible Power
Ariz., Salt River	9,030	20,000
Ariz., Yuma	....	600
Cal., Orland	....	....*
Colo., Uncompahgre	....	10,000
Colo., Grand Valley	....	2,000
Idaho, Boise	3,000	3,000
Idaho, Minidoka	10,000	30,000
Mont., Huntley	380	380
Mont., Lower Yellowstone	....	290
Mont., Sun River	....	....*
Mont., Flathead	....	300,000
Neb.-Wyo., North Platte	....	....*
Nev., Truckee-Carson	1,660	8,000
N. Mex., Rio Grande	....	....*
N. Dak., Williston	3,000	3,000
Ore., Klamath	....	....*
Ore., Umatilla	....	75
Utah, Strawberry Valley	1,600	3,500
Wash., Yakima	....	15,000
Wyo., Shoshone	....	....*
Total	27,670	394,845

*Not determined.

The probability is that most of us would advise the Government to keep out of "making and selling," as that is not a governmental function from the American point of view, and has almost invariably led to financial disaster; but it is interesting to get this review from within the departments that are undertaking these colossal business enterprises. Meantime what a Western private utility can do is illustrated vividly by the Pacific Gas & Electric Co., of San Francisco, with which one of our officers, Mr. John A. Britton, is so prominently connected as vice-president and general manager. The company has 16 electric generating plants, including those under construction, with a total rating of 292,573 hp. This rating is divided into 192,973 hp. in hydro-electric plants and 99,600 hp. in steam generating plants.

The overhead transmission and distribution lines total 3289 miles in length, and there are 61 miles of underground lines and 105 substations. The water department reports storage capacity for 50,000,000,000 gal. and 540 miles of irrigation canals, pipe lines, etc. In the gas department there are 15 plants rated for an output of 40,000,000 cu-ft. per day. There is also a street railway system in Sacramento having 39 miles of track and 62 cars. The company now has under construction a station at Spalding, on the Bear River, which will have an output of 35,000 hp. It will have steel transmission towers. Copper conductors will be used in the snow belt and in the fog belt, and aluminum in the valleys. The transmission tension will be 115,000 volts, with suspension-type insulators. A private right-of-way from the power house to Cordelia, the center of load of the Pacific Gas & Electric Co.'s system, has been purchased, and a double tower line, approximately 118 miles long, each tower carrying a single circuit, will transmit the 115,000-volt energy to the substation at Cordelia, where the tension will be reduced to 60,000 volts, at which pressure the energy will be fed into the company's existing distribution system. It is the expectation of the company to finish another station in 1914, and a third station in 1915, so that the aggregate development now under way approximates 135,000 hp. As indicative of the rapidity with which the load on the system is increasing, it might be mentioned that from the first of the year, 1912, up to October 1, the company had acquired a connected load of 61,000 hp. When the work now under contemplation is complete, the Pacific Gas & Electric Co.'s hydro-electric system alone will aggregate 225,000 hp.

Attention may be called to the automatic pumping station at the Mill Creek, Utah, plant of the Knight Consolidated Power Co., which illustrates a singularly clever and ingenious method of conserving water supply in a territory where water is precious and the available amount limited. The situation is briefly this: A plant working on the somewhat scant and variable supply of a mountain stream, fortunately rendering available a head of over 1000 ft., at certain seasons of the year found itself painfully short of water. Had there been a second stream available, it would have paid to go to considerable expense to add its flow to that of the primary source of power. This has often been done to meet the exigencies of increasing load and stationary water supply.

In the present case no such auxiliary stream was available at or near the level of the main supply. A group of springs, however, at a lower level gave hope of additional water in paying amount, and the bold expedient was adopted of pumping this water supply to the level of the main headworks by electric power. And a cubic foot of water which one can drop more than 1000 ft. on to the wheels below by pumping it less than 150 ft. is not a source of energy to be held in contempt. The project as actually carried out involves an automatic pumping station driven by the simplest form of induction motor directly coupled to a centrifugal pump capable of delivering 3.5 cu-ft. of water per second against a head, including friction, of 138 ft. The little pumping plant requires no attention. The result is very interesting. Except in May and June, when the primary water supply outruns the capacity of the pipe line, it pays to pump the spring water. At normal load it takes 67 kw. to deliver the 3.5 cu-ft. per second at the upper level, and this quantity of water represents 237 kw. at the generators below. There is, therefore, obtainable at the expense of the pumping plant 170 additional kw. for ten months in the year, rising to a yearly output of nearly 1,250,000 kw-hr. It is sufficiently obvious that this additional supply, as large as that delivered by the central station in many a small Eastern city, is a valuable asset. In point of fact, the saving would be more than enough to pay for the pumping plant in a single year.

Illustrative alike of the advances in the art and the financial perils that it encounters, so persistently overlooked by those who assume that every water power is a gold mine when it is not infrequently a gold brick, is the fact that the Southern Aluminum Co., a French concern with French capital, has decided to abandon its hydro-electric development on the Yadkin River at Whitney, N. C., to build a new dam several miles below the present site. According to the tentative plans, the magnificent masonry structures at Whitney, comprising a solid granite dam of cut stone, 1000 ft. wide and 38 ft. high, the spillway of similar dimensions and material, at right angles to the dam, and the canal leading from the dam, will all be submerged and the entire investment, representing at least $3,000,000, thrown away. The new dam will be of concrete, about 1200 ft. long and 150 ft. high. Its construction will involve an expenditure of about $2,000,000.

The Whitney development as a whole has been watched with some misgivings ever since its inception in 1901. The late George Whitney, of Pittsburgh, was the leading spirit in the movement to establish an electric generating plant on the Yadkin River, and the development bearing his name antedated the hydro-electric developments of the Southern Power Co. and of the other great systems in the South. Pittsburgh contractors built the dam, spillway and canal on what was said to have been a basis of cost plus 20 per cent. The work was the finest ever undertaken in the South, the granite being cut, and set with instruments. Like nearly all subsequent developments in that region, the purpose of the development was to generate 10-hour to 12-hour power for cotton-mill operation. By the construction of 4.5 miles of canal, 40 ft. wide and having a depth of 18 ft., a head of 120 ft. could be obtained and approximately 45,000 hp. developed. In the panic of 1907-1908 the entire enterprise had to be abandoned. At that time the dam, spillway and canal were nearly complete, but nothing whatever had been done on the power house. French capital was heavily interested in the original developments, and since the same financial houses are represented in l'Aluminus Française the present ownership of the plant is explained. After the Southern Aluminum Co. acquired the property, at a price placed by rumor at $750,000, it established offices and engineering quarters at Whitney, proposing to undertake its own engineering work. Up to within a few months ago Dr. Heroult, the well-known French engineer, acted in an advisory capactiy, but he has since severed his connections with the company.

The reason given for the abandonment of the Whitney development was that the site does not permit sufficient storage of water for 24-hour operation. By locating farther down the stream a higher head is obtainable and water will be backed up the river for a distance of about 9 miles, submerging the top of the older masonry dam at Whitney. The change of site will, of course, necessitate changes in the contemplated generating equipment, depending on the location of the aluminum plant. If 250-volt operation is no longer feasible, plans are proposed for a 500-volt current layout, using alternating-current generating equipment with rotary converters. To locate the aluminum plant at the power house will require extensive grading of the hillside, costing considerable money. On the other hand, if the aluminum

plant is located even a short distance from the generating station the feeder investment, supposing that seven 500-kw. 250-volt units are still retained, will be prohibitive. The company owns 10,000 acres of land along the river and at Whitney, although the nearest bauxite deposits are said to be at Rome, Ga.

As to record distance of transmission it may here be stated that by the 1st of May, consumers of electrical energy in Santa Maria, Cal., expect to receive electricity generated in the Sierra Nevada Mountains, approximately 300 miles away. This is the first transmission line erected by the San Joaquin Light & Power Co. for supplying electricity to towns on the coast. Several months ago a franchise was granted to the generating company, and since that time the local generating stations at Santa Maria, Arroyo Grande and Paso Robles have been absorbed. Arrangements are now being made for changing over the motor and lighting load from the old plants to the new system. Besides being used for power and lighting purposes in business and residential districts, the electricity will be used for operating the irrigation wells on ranches.

For a number of years the Davis & Weber Counties Canal Co. has operated an extensive irrigation system supplying a large district near Ogden, Utah. By means of a canal extending far up the famous Weber Canyon and paralleling the Union Pacific railroad's right-of-way, water is diverted from the Weber River and led out through a concreted channel which for miles skirts the foothills and marginal slopes of the lower river, supplying water to the farms below and beyond. Realizing the water-power possibilities of the project originally installed for irrigation purposes, it was found possible to develop over 13,000 hp. with the 200-ft. head available between the canal and the river. Of this total capacity, an initial installation of 3750 hp. has now been completed. At the point selected as the most advantageous for this development the river flows on the far side of an old broad flood-plain (now rich farmland), bringing the natural discharge channel more than half a mile from the hillside canal. The water-power plant was accordingly located at about the midpoint of this 2800-ft. distance, being supplied through steel penstocks 1400 ft. in length while a tailpiece of about the same length had to be excavated to connect the turbine draft tubes with the river. In many respects the new Riverdale plant is therefore unique, having huge

steel penstocks of extraordinary length under full hydraulic head and special features of design to control and withstand the unusual natural and impact forces involved in these great moving masses of water. Utilizing its own available resources to the limit, the plant also "borrows" the flow of an independent irrigation ditch, later returning it to the lower channel by means of a centrifugal pump after extracting the net energy of nearly 200 ft. of fall, which would otherwise be wasted. In spite of the difficult natural conditions to be overcome and the completeness and excellence of its equipment, the present plant has been erected at a very low cost, declared to have been less than $45 per kw.

The point of diversion of the main irrigation-ditch supply is in the Weber Canyon, eight miles from the power house. The 30-ft. channel has been concreted, rendering it waterproof and permitting higher velocities of stream flow without danger of "washing" the sides. Originally 325 cu-ft. per second was the water allowance granted the irrigation company, but this quantity has since been augmented by additional fillings of 300 cu-ft. per second. These amounts do not include, however, the 18 cu-ft. per second obtained from the Riverdale ditch which passes the plant. From September 15 to April 15, 643 cu-ft. per second is thus available for water-power use. During the remaining months of the year which comprises the irrigation season only 318 cu-ft. can be taken.

As initially installed, there are at present two principal water-wheel units, one of the 2500-kw. and the other of 1250-kw. rating. Each is separately supplied from the gatehouse through its own steel tube, about 1400 ft. in length. To form the forebay, the 30-ft. concrete-lined canal on the side of the hill has been widened to 60 ft. for a distance of 250 ft., providing a basin which is in part closed on the plant side by the gatehouse. This concrete and brick structure provides four penstock openings, including two future outlets for additional 2500-kw. units. Trash traps protect the intakes of the present penstocks, which can be closed respectively by 96-in. and 72-in. sluicegates, operated by 3-hp. induction motors. These gates work under 19-ft. head and can be manipulated from the power house or from the gatehouse itself, as desired. In the first 400 ft., the penstock tubes drop 173 ft., reaching the flood-plain surface, on which they are carried, practically level, for nearly 1000 ft. to the power house.

Among recent developments is that of the Central Georgia Transmission Co., organized for the delivery of energy over a considerable territory in middle Georgia contiguous to the region already supplied with energy by the Central Georgia Power Co., from which the transmission company buys its energy on a long-term contract. The transmission lines connect Atlanta, Hampton and Monticello with the system of the generating company, and substations in each place take care of the local distribution. Energy is transmitted at 66,000 volts and delivered to customers at 11,000 or 2300 volts. The conductors forming each circuit are on a single side of the pole, but not directly over each other, being slightly staggered to lessen the possibility of contacts due to a heavy load of sleet. The span is only about 550 ft. Each tower carries two stranded steel cables grounded at each pole for protection against lightning, which is considerably to be feared in this particular territory. The transmission circuits themselves are of No. 0 equivalent-stranded aluminum. Two miles of the main circuit pass through the suburbs of Atlanta, running along the curb line of the street, and here, of course, it became necessary to occupy less ground area and thereby reduce the support to what is really a carefully designed square latticed pole, which carries the conductors in precisely the same way as the other towers but on a slightly shorter span, some 425 ft. on the average. Another interesting part of the system is a large switching tower near the Hampton substation. This is a latticed steel structure supporting in the free open air the group of long switches for sectionalizing and interconnecting the lines at this particular point. In some of the Pacific Coast plants the open-air switching system has been used very successfully, and not uncommonly it forms an addition to power houses and substations, but its use in Eastern plants has been somewhat limited, so that this Southern example is rather a striking one. But there will be more of it.

The recent rounding out of the system of the Pacific Power & Light Co. with headquarters at Portland, Ore., and its plans for further development, are typical of the way such systems grow under energetic management and subject to the demand of the region for service. At the end of 1912, the company had in operation about 350 miles of 66,000-volt line, classifying under this head the line between White River and Hood River, which

is not now operating at this voltage but which will be by the end of summer. The company also had 73 miles of 22,500-volt lines, most of which is double circuit on a single pole line, making a total of about 125 miles of single line of this character. Not counting city distributing systems, it is estimated that the company has 250 miles of 6600-volt lines in the rural districts. The operation of these transmission lines, between 500 and 600 miles of which are bound together in one system, was an interesting problem for the company to solve when it was first undertaken. The generating plants are not large and the charging current required by the lines was relatively high, but the load dispatcher has been located at Kennewick, near the middle of the Yakima-Walla Walla line, which makes the situation such that it can be handled very satisfactorily. The interruptions are few. During the summer months small cyclonic wind and dust storms sometimes visit the territory and these play havoc with the transmission and distributing systems.

Some of the transmission lines extend over isolated country and to keep them properly patrolled is also an important function of the operating department. Some lines have been built over mountain ranges which has necessitated that every pole hole be blasted out of bed rock, and the line from North Yakima to Priest Rapids makes a remarkable descent from the mountains above Priest Rapids power house down the Columbia River at an angle of about 45 deg. Material for lines of this character had to be hauled many miles over almost impassable roads through rocks and sagebrush and had to be let down over cliffs with ropes.

The American Power & Light Co.'s allied interests have under contemplation the construction of an extensive development at Priest Rapids, on the Columbia River, where 1800 kw. is now being generated by the Hanford Irrigation & Power Co. The available power at this place has been estimated at from 100,000 hp. to 300,000 hp. The river is not navigable at this point and the proposed development would include locks for the convenience of river boats which together with the canal now being finished near The Dalles by the Government would make the Columbia River navigable from its mouth almost to the British Columbia line. Another available source of supply for the Pacific Power & Light Co. is provided by contract with the Washington Water

Power Co., which stipulates that the Pacific company can extend its transmission line to Lind, Wash., and there make connections with the 60,000-volt line which has already been built to that place from Spokane. The Washington Water Power Co. has an abundance of power and has arranged to make Lind the transfer point.

Another concern with a similar name to that just mentioned is doing some spectacular work in California. The Big Creek Development in central California reached after a climb of over 50 miles into the mountains on a railroad built by the Stone & Webster Construction Co., the contractor for the entire work, is not only one of the largest but in several respects is the most interesting undertaking in the country. In addition to involving the highest voltage for transmission over the longest distance yet attempted, the installation possesses many features of interest from the purely hydraulic standpoint. If a straight line be drawn, extending from San Francisco to Los Angeles, and from a point on this line slightly over a third of the way down another line be carried at right angles 100 miles eastward into the heart of the State, its further end would mark the site of the Big Creek operations. The point is 175 miles from San Francisco and 275 miles from Los Angeles, and the elevation is about 7000 ft. In the total installation a fall of 4000 ft. will be utilized to generate 120,000 kw. for the system of the Pacific Light & Power Corporation, which already has an aggregate equipment rating of 70,000 kv-a. in six hydro-electric and three steam plants. The Pacific Light & Power Corporation serves a population of 400,000 in Los Angeles, and surrounding towns such as Pasadena, Riverside and San Bernardino. The scheme involves the construction of two power houses, each of which will have an ultimate equipment of 60,000 hp. in four wheels, of which two will be installed initially, and the plants can be operated independently. The generating units will be 3-phase 6600-volt machines driven by two overhung impulse wheels on the same shaft. The combined rating of the two wheels of each unit will be 20,000 hp. The current will be stepped up to 150,000 volts for the line of 275 miles, which will consist of a double set of steel towers, each supporting three steel-cored aluminum conductors arranged horizontally. The line will stand largely on a private right-of-way.

The annual rainfall of the Big Creek watershed is more than 80 in. for an average year, and the run-off is equivalent to at least 50 in. Three gravity-section, concrete dams, two 100 ft. and the third 164 ft. in height, will close all the natural openings in the basin. These dams will be built upon solid granite formation, the construction material with the exception of the cement being available close at hand. Upon leaving the basin, Big Creek drops about 4000 ft. within a distance of six miles. With such a great difference in elevation, and with a reservoir to equalize the flow of the stream, a comparatively small amount of water is necessary for hydro-electric development. If there were no inflow for five months, it would probably be possible to operate during that period on storage alone, assuming a 50 per cent load-factor. From the reservoir the water will be led southwest through a 4000-ft. tunnel cut in solid granite to a steel flow pipe, which will continue 6800 ft., along the surface to the mountainside above Big Creek. Here the water will enter pressure pipes and drop about 2100 ft. through the wheels of power house No. 1 to the forebay of a second tunnel, to be formed by a dam, 70 ft. in height, built across the bed of the creek. Tunnel No. 2 will carry the water through solid granite to the crest of the gorge, about four miles southwest of power house No. 1. From the outlet of this tunnel the water will enter pressure pipes and fall about 1900 ft. to power house No. 2. It will be possible to generate about the same power at each of the plants, as the forebay of the second tunnel will be located at a point just below the juncture of Pitman and Big Creeks, and the additional supply of water will increase the power available at station No. 2 and in a measure compensate for the difference in static heads at the two plants. The power house will be built of reinforced concrete.

The Southern Sierras Power Co., a subsidiary company of the Nevada-California Power Co., of Denver, Col., completed last year a double, 3-phase, high-tension, steel-tower transmission line northward from its San Bernardino (Cal.) plant, through the Owens River valley for a distance of 236 miles to Bishop (Inyo County), where the company has two hydro-electric developments with an aggregate rating of 4000 hp. The Southern Sierras Power Co. owns and operates a 5000-hp. steam turbo-generating and distributing system at San Bernardino, the distributing system at Corona (Cal.) and also an 80-mile distribut-

ing system covering the San Bernardino, Riverside, Corona, San Jacinto and Perris Valley districts, embracing in this territory a thickly settled community of at least 50,000. The hydro-electric stations are on Bishop Creek, a tributary of the Owens River. One of the stations in operation has a rating of 2000 hp., while another of the same rating has recently been under construction.

One of the interesting developments of the year is the 27,000-hp. hydro-electric plant of the Eastern Tennessee Power Co. on the Ocoee River at Parskville, Tenn., by J. G. White & Co., Inc., who were the engineers and contractors for this plant. The dam, built of concrete, is 840 ft. long at the crest and is from 115 to 125 ft. thick at the base, with a spillway 362 ft. in length. The water enters the penstocks at a point about 30 ft. below the crest. The main building of the power house, 165 ft. long and 35 ft. wide, situated immediately below the dam, of which its superstructure is an integral part, contains five main generating units, each rated at 5400 hp. when operating under 98 ft. head at 360 rev. per min. The energy is generated at 2300 volts, the e.m.f. being raised to 66,000 volts by transformers housed in a wing at the north of the main building. In addition to the 27,000 hp. which will be available from this plant, provision for a secondary development of 11,000 hp. at Parksville has been made by building two openings in the dam, to which penstocks leading to a power station about 400 ft. below the dam will be attached. The energy available from this source will be used as a reserve to the main plant. Besides these plants, a second development of 20,000 hp. is now under construction on the Ocoee River, the available water-power resources of which aggregate 75,000 hp. Energy is transmitted at 66,000 volts over two 3-phase circuits to Cleveland, Tenn., a distance of 13 miles from the plant; and from the switching station in Cleveland, where the lines separate, the energy is carried over single-circuit wood-pole lines 26 miles west to Chattanooga, Tenn., 85 miles north-east to Knoxville, Tenn., and 75 miles south to Rome, Ga.

During the year, the Great Western Power Co., of San Francisco, Cal., in addition to enlarging its generating station on the Feather River by the installation of two 10,000-kw. units, has built a dam at Big Meadows, Plumas County, 25 miles from Keddie on the Western Pacific Railroad. The dam is of the multiple-arch type, 700 ft. long at the crest, constructed of concrete

heavily reinforced with iron. It consists of a series of concrete buttresses, spaced 30 ft. apart, from center to center, in a direction parallel to the flow of the stream and with a series of arches on the upstream side, each arch covering the space between two buttresses. These arches are inclined so that the weight of the water behind the dam exerts pressure downward, thus increasing the stability of the structure. The dam has a maximum height of 110 ft. above the ordinary water level of the stream flowing through the meadows and impounds a lake 40 square miles in area and storing 1,255,000 acre-ft. (54,540,000,000 cu-ft.). When completed the flow of the Feather River will be regulated from a minimum of 1000 to 2500 cu-ft. per second. This plan enables the company to develop at the Big Bend station 80,000 kw., which is the limit to the power available on the site owing to the size of the tunnel through which the water is conveyed. Under ordinary conditions it will require almost three years to fill the reservoir created by the dam.

An unusual hydro-electric plant put into commission the past year is that which harnesses a head of 181 ft. from the "Thousand Springs" rising from lava beds in Idaho. Practically the whole State of Idaho and parts of Utah and Nevada are overlaid with a great lava sheet which covers the sedimentary country rock in places to a depth of several hundred feet. This lava rock, now hardened and more or less impervious to water, lies on a sandstone equally impervious. But in the plane of contact between these two formations underground streams are collected and flow for miles without meeting the light of day. In southwestern Idaho, where the Snake River has cut its channel more than 300 ft. deep through the 100-ft. surface layer of igneous lava outflow, and then through the softer sedimentary rocks for 200 ft. more, egress is afforded for one of these underground rivers in a curious way. For a distance of nearly half a mile along the side of the canyon the water pours out into view from the plane of the lava contact, forming the famous Thousand Springs. The source of the water itself is unknown and certainly is not within 100 miles of the point where it emerges from its underground channel. The stream has an average flow of about 750 cu. ft. per second and is very uniform in character, varying little during the seasons of the year. From the level where it emerges, 100 ft. below the top of the canyon, a head of 181 ft.

is available down to the Snake River, which flows below, and here a 3000-hp. water-power plant is now being constructed, with provision for future extensions to 12,000 hp. to utilize the full flow of the Springs. Many different attempts have been made in the earlier years to collect and utilize the flow from the Thousand Springs, but without success, owing to the peculiar nature of the problem, the difficulty of foundationing structures on the side of the cliff and the long contact outlet of the water. The final solution carried out in connection with the present development, was the erection of a concrete canal wall on the side of the cliff at the outflow level. This wall is 400 ft. long and in places 16 ft. high. It forms a canal 20 ft. wide, whose other side is the native cliff and in which the water from the numerous spring outlets is collected. At one end for a distance of 150 ft. the canal is widened out to 40 ft., forming a forebay opening to the penstocks which lead to the power house, nearly 200 ft. below. Though the Thousand Springs development is capable of providing 12,000 hp., the initial machinery is only two 1500-hp. units. Spiral scroll-case Pelton-Francis waterwheels, operating under the head of 181 ft., drive Westinghouse 2300-volt, 60-cycle, 3-phase alternators. No gate valves are provided for the penstock tubes, but quick-closing headgates are inserted at the tops of the pipes. These headgates are hoisted by worm-geared motors, although it is possible to close the gates almost instantaneously from the power-house floor, by means of a tripping rope allowing the gates to fall shut. From the alternators the e.m.f. of the 2300-volt, 60-cycle energy is stepped up to 40,000 volts for transmission to Idaho points, where the energy is chiefly used for irrigation pumping. The hydro-electric site is eight miles south of Windell, Idaho, on the Snake River. The development is being made by the Thousand Springs Power Co., of which Mr. Lafayette Hanchett, of Salt Lake City, Utah, is general manager.

The plant at Great Falls, Mont., has more than once been referred to, but its magnitude is not generally known. Generating 21,000 kw. at a dam 29 feet high and 1146 feet long, the system transmits its energy from the Rainbow Falls at a pressure of 102,000 volts no less than 152 miles to the mines of Butte and Anaconda. The upper Missouri drops nearly 400 ft. within a few miles of Great Falls, and the topography is such that the power sites are easily developed. One of these is within

the city limits largely utilized for great smelting works, and only in part for power transmission. Four miles below the city lies the site of the present development on the crest of the Rainbow Falls. Two huge steel pipe lines, 15 ft. 6 in. in diameter, leave the forebay at the dam and run for half a mile to a balancing reservoir above the power house, which serves as a buffer or great relief valve between the flow from the dam and the varying demand of the wheels. This renders the task of regulation vastly easier than would otherwise be the case and simplifies the construction of the pipe line. These pipes when filled hold 56,000,000 lb. of water, and the hydraulic forces would be stupendous were the conditions such as to permit the act of governing suddenly to demand even a slight change in velocity.

The transmission structure is of more than usual interest. It is a double-tower line, each set of towers carrying a single circuit with the conductors spaced 10 ft. apart on the same level. The towers are somewhat lower than early tower practise would show, supporting the wires only 40 ft. from the ground. Each conductor is a 6-stranded hemp-centered copper cable borne by six 10-in. disc insulators tested wet for 300,000 volts from conductor to arm. At the tower tops are carried, symmetrically placed between conductors, a pair of 3/8-in. galvanized-steel cables serving as ground wires. The actual pressure is 102,000 volts, so that the factor of safety with respect to the insulators is very nearly three, an unusually good figure in transmission practise. The normal span between tower and tower is 600 ft., although there are various long spans in the line, one of them a little over 3000 ft. at the crossing of the Missouri.

Each of the separate transmission circuits is sectionalized at intervals of about 20 miles with disconnecting tower switches. The telephone circuit is on a separate pole line midway between the two tower lines. The high-tension circuits are not transposed at all, but the telephone circuit is spiraled every five poles. In the operation of the line it is interesting to note that, thanks to a large motor load at Butte and three 1200-hp. synchronous motors at Anaconda to compensate the wattless volt-amperes, the power-factor at the Rainbow Falls bus-bar is held steadily at almost unity. Very little corona is visible on the lines, although the loss due to this cause amounts to about 2 kw. per mile. The load-factor, owing to the unusually steady use of motors on the

system, is extraordinarily high, averaging about 86 per cent on an annual basis.

At Butte, emergency throw-over service is afforded by the Butte Electric & Power Co., which in turn has water power plants over 20,000 kw. on the widely apart watersheds which embrace the Yellowstone, Madison, Jefferson and Big Hole Rivers. Moreover, at Great Falls itself is available another 75,000 hp. for future development.

At Long Lake, west of Spokane, has been under construction a new plant for the Washington Water Power Co., with the highest spillway dam in the world. It is 200 ft. in total height, a fall of 170 ft. has been created, and a storage lake 23 miles in length and averaging 3/8 miles in width has been made. Considering only 15 ft. of storage, the water thus held for reserve will amount to 2,695,000,000 cu. ft., all of which will be available not only for the Long Lake plant but also for the older one at Little Falls. The dam to be constructed is unique in at least two important particulars. Owing to the topography it has not been considered feasible to provide a spillway for flood waters except over the dam itself. This means that the dam will not only be higher than any other spillway dam now in existence, but it will at times of flood carry about 19 ft. of water over its crest. It has been determined to hold the low-water level of the lake at the same level as at high water. This is being accomplished by the use of three roller dams of German type, mounted upon the crest of the spillway. Each roller is 65 ft. long and 19 ft. deep and is operated by suitable power mechanism. The plant will consist of an ultimate installation of four 13.900-kv-a. generators having a continuous overload capacity of 25 per cent. Each generator will be connected to an I. P. Morris waterwheel rated at 22,500 hp., the largest waterwheels ever built.

The Washington Water Power Co., for which this new plant is needed supplies electrical energy to Spokane, Wash., as well as to all the towns and cities in the Inland Empire within a territory extending approximately 100 miles east, west, north and south of that city. It has 534 miles of 60,000-volt transmission line, two sections of which feed the Cœur d'Alene mining district in Idaho, the biggest producing lead-mining center in the world. From Spokane, Wash., to Wallace, Idaho, two independent lines traversing different routes carry the electrical energy

to the center of the lead-mining district, nearly 100 miles east of its point of generation. This Cœur d'Alene camp alone is said to produce more than one-third of the lead output of the United States. Another high-tension line extends south for nearly 65 miles into the fruit-raising Palouse country, one of the greatest wheat belts in the Northwest. From this line the towns along the route are lighted, the flour mills operated and electricity is distributed for general use. Still another line extends 117 miles into the Big Bend country contiguous to the Columbia River, where is a rich fruit-growing and wheat-raising addition to the older Palouse country. The line to the north extends as far as Newport in the lumber region, traversing also a part of the State of Idaho. In Spokane the energy is distributed for the operation of over 24 miles of interurban electric railways and 88 miles of city lines, the company's street-railway system being the largest in the city and its two interurban lines connecting Spokane with Cheney and Medical Lake. The Great Northern shops are among the many industrial establishments supplied in Spokane from its circuits. The company has also splendid municipal and commercial lighting loads, for gas is not used to a material extent in Spokane for lighting, and there is no competition. The system generates a large part of its energy, as is well known, within the very city of Spokane. but has other sources of supply, as at Post Falls, Idaho, and more recently at Little Falls, Wash., 30 miles west of Spokane, with 20,500 kw. capacity.

The Southern Appalachian country is rich in water powers and the development of these has already had a notable influence in the industrial regeneration of the South. From the hydraulic standpoint the situation all through this region is somewhat peculiar. The rainfall in the mountains is rather heavy, but the streams traverse a long stretch of somewhat hilly country presenting only moderate slopes for a long time after leaving the mountains. The mountain sources themselves are usually rather small and numerous and the whole Appalachian territory is characterized by the almost complete absence of natural lakes, although here and there are admirable opportunities for storage. The developments along these streams are therefore on the whole rather low-head propositions with a good volume of water requiring the help of artificial storage if it is to be used at anything like its full value. Nevertheless, the sites are many and valuable.

The developments on the New River are in the southwestern corner of Virginia, less than 20 miles from the North Carolina line and not much further from the West Virginia line. Within a stretch of 25 or 30 miles lie five separate hydro-electric sites taking the full volume of the river and having an aggregate fall of about 225 ft., the total normal development rating being about 75,000 hp. Of these sites Nos. 2 and 4 have now been developed with a total of about 29,000 hp., and from them as a nucleus 88,000-volt lines have been built to Coalfield, W. Va., and Saltville and Roanoke, Va. The electric systems of seven towns in the area have also already been acquired and tied-in. The interesting fact is that this is a coal mine area including the famous Pocahontas fields.

Another recent Atlantic seaboard development, in a region equally under the older conditions and surroundings is Vermont. Until very recently New England was conspicuous for the absence of important networks. What had been done was merely the commonplace installation of a few useful and not very large plants. Three years ago the system of the Connecticut River Transmission Co. was put in operation, starting with a plant at Vernon, Vt., now aggregating about 2000 kw. Its lines stretch eastward to Fitchburg, Clinton and Worcester and, acting as a wholesale dealer in energy, the system has made rapid growth. Now, under the corporate organization of the New England Power Co., another large development is being added to reinforce the system and nearly double its rating. This new enterprise involves the utilization of the Deerfield River, which rises in southern Vermont. The stream, with a total drainage area of a little over 500 sq. miles, is more important than this area would indicate. It has liberal available fall and takes its rise in that plateau of the southern Green Mountain territory which is conspicuous as having the largest rainfall in this part of the country. As in any mountainous stream, the flow is very variable, and one of the important features of the present project is the building of a storage reservoir at Somerset, Vt., to hold 2,500,000,000 cu-ft. of water. Three plants are now being erected, all very similar, each of 6000-kw. rating in three units. The plants are in the immediate vicinity of Shelburne Falls and operate under heads of about 60 ft. each. They are of simple design with details thoroughly rked out and present in themselves no very striking features.

The hydraulic design is in each case comparatively simple except in the case of the upper plant, known as No. 4, in which a tunnel some 500 yd. long had to be cut to give ready access to the fore-bay. Such tunnels are common in the far West but a decided rarity east of the Rockies. The inauguration of service from these new plants, with the interconnection and extension of transmission lines throughout a large part of central and western Massachusetts, means a great deal to the consumers of low-priced energy in the populous municipalities of this intensely active manufacturing and commercial region, and the proposed extension of a 120,000-volt system into Rhode Island gives a new angle of outlook on the future of wholesale electrical distribution in the territory.

Active construction work has been begun on the Coon Creek Rapids development in the Mississippi River, 11 miles northeast of Minneapolis, where a 12,000-hp. plant is to be erected by H. M. Byllesby & Co., to furnish additional power to their Minneapolis and St. Paul properties. The dam is being built under a 50-year permit granted by the United States Government, which requires that the army engineers supervise the design, construction and operation of the development. The dam will consist of an earth embankment with core walls 600 ft. long, power house and retaining section 470 ft. long, including sluice-gates, log chute and fishway, and spillway section 1000 ft. long, making the total length of the structure 2070 ft. This work will involve 20,000 cu-ft. of earth embankment and approximately 45,000 cu-yd. of steel-reinforced concrete.

To secure a suitable and safe foundation, 8000 round wooden piles will be driven down to firm foundation. About 100 tons of interlocking sheet-steel piling will also be used in lieu of a cut-off wall for retention of water in the reservoir and prevention of under-cutting of the dam. In order to provide for the greatest possible head at all stages of river flow, at the same time preventing excessive flood heights, Tainter gates are to be used for regulating the water level in the reservoir. Twenty-eight of these 33-ft. steel gates, each weighing 12,000 lb., will be erected between reinforced-concrete piers built on the spillway portion of the dam. The fishway designed in accordance with Government requirements, will provide for the free passage of fish up

and down stream, and the log sluice will afford a convenient means of passing logs by the dam.

The first installation in the power house will aggregate 12,000 hp., transmitting to Minneapolis at 13,300 volts, thus tying in directly without transformers with the general distribution system of the Minneapolis General Electric Co. at its Riverside steam plant. The transmission line to Minneapolis will be erected for part of the distance on private right of way and partly alongside the new tracks of the Minneapolis & Northern Railroad.

All of the large generating companies on the Canadian side of Niagara Falls have been engaged in building extensions to their systems with a view to utilizing all the water available for power purposes under the existing treaty. The Toronto Power Co. has a number of new units already in place and this year will complete its station, which will have equipment aggregating 125,000 hp. A new line fitted with pin insulators and operated at 85,000 volts will also be in operation between Niagara Falls and Toronto. The Canadian Niagara Power Co. is completing its station building and installing additional units. It will expend $1,250,000 in the next two years in enlarging the forebay so as to be able to get enough water to generate all the electricity that it can dispose of under the treaty. The station of the Ontario Power Co. has been doubled in size and will shortly be completed, and with the installation of two 12,000-kw. units now on order the company will be using almost all of the water granted to it by the Dominion government.

Approval has recently been secured from the Public Service Commission for the Second District of New York State for the transfer to the Niagara, Lockport & Ontario Power Co. of the capital stock of the Salmon River Power Co. This secures to the Niagara company the hydro-electric development on the Salmon River, which is now under construction, some 40 miles north of Syracuse.

One of the provisions in the formal consent of the Commission is that in any investigation or inquiry by the Commission or other lawful authority into the rates or charges for any electric energy generated at the Salmon River plant, whether such rates are made by the Niagara company or by any other person or corporation, the rental provided by the lease shall not be deemed as material or conclusive in any respect as to the reasonable

price or rate to be charged for energy to the consumer, and the Commission will be at full liberty to inquire into the actual cost of generation and base its determination upon such cost and other material facts without regard to the rental.

The acquirement of the Salmon River property by the Niagara, Lockport & Ontario Power Co. was deemed necessary in view of the increasing demand for electrical energy in the Syracuse district and the desirability of avoiding the construction at great expense of a new transmission line from Niagara Falls to Syracuse, a distance of 154 miles. The plans for the initial development of the Salmon River project include a generating plant of 15,000 hp. present capacity, 42 miles of 60,000-volt, two-circuit, steel-tower transmission line and a storage reservoir of 1,000,000 cu. ft. capacity. The Salmon River Co. owns approximately 8000 acres of land, situated about 42 miles north-east of Syracuse, including the river bed of the Salmon River for a distance of approximately 12 miles, in which distance the river has a fall of 330 ft. A concrete dam 600 ft. long is being built on solid rock foundation in order to create the reservoir which will have a superficial area of about four square miles. The storage capacity can be more than doubled by raising the dam 11 ft. The drainage area above the dam is 191 square miles in extent and lies on the westerly slope of the Adirondacks in a region which has one of the heaviest rainfalls in the state. The transmission line will be carried on private right-of-way, sufficiently wide to permit of a duplicate tower line. The Niagara, Lockport & Ontario Co. is now operating its transmission system at practically the full capacity of 60,000 hp. By supplementing the Niagara supply with the energy transmitted from the Salmon River development the company asserts that it will not only be in a position to increase its business in Buffalo and in the territory between Buffalo and Syracuse, but will also be able to improve the quality of service in the Syracuse district.

The boldest project on the American map at the moment is the Hetch-Hetchy water supply and power generating project for San Francisco, for which a 400-page report prepared by the well-known engineer, Mr. John R. Freeman, has been filed with the Secretary of the Interior by the city authorities. The project has been met with strenuous objections, chiefly on the score that it condemns a beautiful valley to utilization purposes. The water

power it is proposed to develop at three advantageous points to the extent of 157,000 hp. available 24-hours daily the year around, with 200,000 hp. available on peaks. The transmission line would be erected chiefly along the aqueduct rights-of-way, 150 miles to San Francisco and 135 miles to Oakland.

The city proposes to build a masonry reservoir dam about 300 ft. in height above the river-bed in the narrow gorge at the outlet of the Hetch-Hetchy Valley, by which the water can be raised about 270 ft. above the nearly level floor of the valley. An aqueduct will be constructed from this reservoir to the city of San Francisco, largely in the form of a tunnel about 10 ft. in finished diameter, mostly deep beneath the surface of the ground. The proposed aqueduct between the Hetch-Hetchy and the Irvington gatehouse on the hillside overlooking San Francisco Bay is designed to deliver, by force of gravity, without pumping, a quantity of water somewhat in excess of 400,000,000 gal. daily, and under extreme conditions possibly 500,000,000 gal. per day. The communities to be supplied will require in the immediate future for domestic and municipal purposes but a small fraction of the quantity of water which can be transmitted by the ultimate development, and according to present plans some of the surplus will be made available, at a moderate meter rate, for irrigation, principally in connection with intensive farming and truck gardening in the San Francisco district.

The portion of tunnel about 12 miles in length next down stream from the Hetch-Hetchy dam will be delayed in construction for some years, and meanwhile the city proposes to divert the water from the main Tuolumne River by means of a temporary dam at a point about 1½ miles upstream from the confluence with Cherry Creek. Tributary reservoirs will ultimately be created at two sites, one at Lake Eleanor and the other at Cherry Creek, discharging into the Hetch-Hetchy through an 8-ft. underground tunnel.

The city does not propose in the immediate future to construct any plant for the development of hydro-electric power, but plans to conserve carefully all reasonable opportunities for power development against the time when it may become expedient to undertake such developments.

We shall have a lecture during this Convention from the distinguished engineer Mr. Hugh L. Cooper on the work at

Keokuk, Ia., where the Mississippi River Power Co. is developing its splendid plant, with an initial rating of 150,000 hp. and an ultimate rating of 240,000 hp. at a cost of about $25,000,000. Taking advantage of the prospect of this cheap hydro-electric energy from a source 140 miles away, the Union Electric Light & Power Co., of St. Louis has issued an interesting booklet entitled "Our Dream Comes True," and referring to St. Louis under the title "A City of Power Without a Peer." It is related that, after years of planning, St. Louis will shortly have electrically transmitted energy from the Mississippi River in a practically unlimited amount. It is intended to make St. Louis one of the great energy markets of the world. The hydro-electric energy will be distinguished from steam-produced electricity by the designation "unrefined." It will be supplied to customers in blocks of 200 kw. or over in the form of 13,200-volt, 25-cycle energy. The purchaser must provide or pay for his own transformer installation. Under these conditions the net rate for this energy will be $20 per kw. per year for the first 200 kw. of demand and $15 per kw. demand per year for all excess, plus an energy charge of 0.5 cent per kw-hr. Comprehensive distribution plans have been worked out providing that the "unrefined" energy shall be available in all parts of St. Louis for manufacturing purposes.

Pending the delivery to the St. Louis company of the hydroelectric energy, the company has offered to enter into contracts at the wholesale high-potential rate mentioned, delivering the energy in the meantime from its Ashley Street generating plant. When completed the Keokuk plant will have a rating of 100,000 kw. or over, and ultimately 60,000 kw. of this or more will be transmitted to St. Louis, a distance of about 160 miles.

In somewhat similar manner, the Milwaukee Electric Railway & Light Co. placed in effect last year a new schedule of rates for electrical energy supplied exclusively from hydro-electric sources, under terms somewhat unusual and interesting. Energy is delivered at a rate of not less than 200 kw., without any guarantee of continuity of service, and subject to the vicissitudes of hydro-electric generation, long-distance transmission and transformation. Only customers whose load consists of motors and miscellaneous lighting are permitted to contract for this form of service. Electrical energy is delivered at a pressure of approximately 13,200 volts, 3-phase alternating current, at a frequency

of 25 cycles; or in place of the delivery voltage stated above the pressure may be any other transmission voltage. The customer is required to furnish the transformers, switching apparatus and lightning protection, of a type or types to be approved by the company. The latter states that this service should be taken only by customers having their own steam plants to serve as emergency reserve, and, furthermore, the service is offered only where delivery can now readily be made and the company does not obligate itself to extend its underground transmission system to make delivery.

The form of rate schedule consists of a demand charge plus an energy charge, with a minimum bill and discount for prompt payment. The demand charge is $20 per kw. per year for the first 200 kw. and $15 per kw. per year for all demand in excess of 200 kw. payable in equal monthly instalments. The energy charge is 7 mills per kw-hr. for all energy consumed during each month; the minimum annual demand charge is $4,000. On bills paid within ten days a discount of 5 per cent is allowed on the first $25 of all bills, and 1 per cent on amounts in excess thereof. The company limits the amount of hydro-electric power to be sold to 10,000 kw. A customer's demand is determined as the maximum rate at which energy is used for any period of 15 consecutive minutes, and may be ascertained at the option of the company by counting the revolutions of the watt-hour meter disc, or by printing the watt-hour meter readings at quarter-hour intervals, or by the curve drawn by a recording wattmeter. The maximum demand charge during any month is not less than that computed from the basis of 75 per cent of the maximum charge during any previous month of the contract period. Consumers are not permitted to sell or otherwise dispose of any of the energy to any individual or corporation without the consent of the company. The measuring instruments or apparatus for determining the customer's demand and consumption are supplied by the company and are connected on the primary side of the customer's transformers or other equipment.

If the company's measuring instruments should fail at any time to register the energy used, the amount for the month during which a stoppage may occur is computed at the same average rate as for the two months next preceding, or, if energy has not been supplied during the two preceding months at a normal rate,

then the next succeeding period of two months is used as a basis. Proper allowance is also made in case energy has not been used regularly during the months in which the stoppage occurred. Provision is included in the standard form of contract whereby the company may suspend the delivery of energy on Sundays and legal holidays for the purpose of making repairs, changes or improvements upon any part of its generating or distributing system, provided, however, that reasonable notice is given to the consumer. In the case of shut-downs of the last-mentioned character no reduction of the demand charge is permitted.

A GLANCE ABROAD

Having now touched on some of the typical "high spots of recent American hydro-electric development, and recent power transmission work," we may take a swift glance abroad as to what is doing there, and get a few quick-shutter impressions of work not less notable than our own for boldness and progressiveness. Canada is of course nearest home. The National Hydro-Electric Co. has taken further steps toward supplying Montreal with power from its proposed plant at Carillon Falls, Quebec. A small plant is already in operation, but it is planned to build a very extensive installation, which Mr. Miles, the president of the company, declares will cost $10,000.000 and will be capable of developing 160,000 hp. Power from the small plant is to be used for the construction of the larger one and also to supply neighboring municipalities. The company has a Dominion charter, enabling business to be done in the Province, and application has now been made to the Provincial Legislature to grant the right of placing poles and wires in municipalities without dealing with each one in particular. The right is also sought to use the Montreal conduits for the company's circuits. Among the places in which the company asks permission to operate are Assomption, Terrebonne, Two Mountains, Jacques. Cartier, Laval, Montcalm, Joliette, Berthier, Richelieu, Missisquoi, Vandreuil, Argenteuil, Soulanges, Chambly, Chateauguay, Beauharnois, Ottawa, Iberville, St. John and Labelle. The first issue of bonds and debentures is $12,000,000.

Plans are under way by the Nova Scotia Power Co., Kentville, N. S., for the construction of a hydro-electric plant at White

Rock, at the head of the Gaspereau Valley, for the supply of electrical energy to Halifax and the towns of Kentville, Wolfville, Windsor, Canning and Middleton. The project calls for the utilization of a drainage area of about 160 sq. miles on the so-called South Mountain watershed, lying from 50 to 75 miles west of the city of Halifax, and includes the interconnection of a double chain of reservoirs and lakes and the construction of a main dam at the foot of Gaspereau and Murphy Lakes, with canal and flume facilities connecting with Little River Lake and the power-house site. About 3 miles of canal and 5 miles of flume are to be built, and the developed head at the generating plant is to be about 475 ft. A steel penstock about 2000 ft. long will be installed at White Rock, with a forebay at the top. About twenty lakes are involved in the storage scheme and the total power available is estimated at 18,000 hp. with the ultimate development. The principal dam will be at Beaver Brook, and will be about 6000 ft. long and 25 ft. in height. According to present plans, a 60,000-volt, steel-tower line will be built between the power house and Halifax. The intermediate territory is now supplied with electrical facilities from a number of small and relatively inefficient steam plants giving no day service. These will be shut down entirely and a considerable agricultural business will be established, including the operation of numerous apple and potato hoists in the Annapolis and Cornwallis valleys, the former crop averaging from 1,000,000 to 1,500,000 barrels per year. The utilization of a substantial amount of energy in Halifax is expected.

Continuing within the British domain, it may be noted that ambitious projects are being contemplated or carried out at the Antipodes. Among the schemes under consideration by the officers of the Public Works Department of New South Wales, is a project for generating electrical energy at one of the coal fields in the southern part of the State for delivery to the populated areas not now served by the Sydney City Council. They are also considering the establishment of electrochemical industries for the manufacture of calcium carbide, cyanamide and caustic soda. It is estimated that the demand for electrical energy by the State enterprises and by the municipalities and private enterprises in the southern area will be so great that it will be imperative for the government to take the matter in hand. The scheme just

mentioned provides for the joint utilization of the State coal and water-power resources through the establishment of a generating station in each of the important coal fields and upon those streams which may be depended on to provide sufficient power to justify their commercial development. It has been proposed that the scheme be launched with the initial establishment of a large plant at some convenient point on the southern coal field, either at Picton or Wollongong. The general plan contemplates that this station will eventually be linked by transmission lines with stations at Burrinjuck, on the Shoalhaven River, and in the other coal fields. Towns along the routes of the transmission system or within reasonable distance would be supplied with service.

New Zealand is an area of large water powers, but its electrical enterprises seem to have suffered a good deal from being in the hand of the government with the consequent suppression of individual initiative and enterprise. This is demonstrated by the available statistics. Being a well-watered and mountainous country, New Zealand is rich in water-power resources. According to statistics for 1910, supplied by the machinery department of the government, the total development of water power in New Zealand is only 19,353 hp. This represents only 9.5 per cent of the total present power supply (exclusive of railways) in New Zealand, amounting to 204,458 hp. of which 150,000 hp. or 73.4 per cent, is supplied by steam engines, 23,456 hp. or 11.5 per cent, by gas engines, and 11,512 hp. or 5.6 per cent, by oil engines.

Among the larger proposed hydro-electric developments is one at Lake Coleridge, of 14,000 hp. which is very favorably situated for water storage, inasmuch as the lake has an area of 14 sq. miles. The energy will be transmitted, according to the plans, to Christchurch, 70 miles distant. Next in importance is a proposed development on the upper Hutt River, of about 17,000 hp. for the benefit of Wellington and other towns in the vicinity, requiring a 31-mile transmission. The Lake Coleridge plant would operate with a 470-ft. head and the latter with a 285-ft. head. Another scheme contemplates a large development at Lake Rotoiti in the hot-springs district, with a 170-mile transmission to Auckland, delivering 26,000 hp. Several other projects of a more ambitious character have been proposed, but are not seriously considered at present and are not likely to be until the population increases.

The demand for electricity for industrial purposes, such as for factories, mining, tramways and street lighting, and for domestic lighting, heating and cooking, is increasing constantly. The public has become so educated to the use of electricity that the need for its cheap development by water power is well recognized by the government authorities, who now feel that, unless they are prepared to permit private capital to establish water-power works, they can no longer refrain from committing themselves to the necessary expenditures and risks.

Among the electrochemical industries suggested for New Zealand in connection with the development of its water power is the manufacture of calcium carbide, the imports of which are increasing each year, having been 898 tons in 1907, 932 tons in 1908 and 1667 tons in 1909. The local manufacture of this article would be favored by the fact that the freight rate on it from Europe to New Zealand and Australia is very heavy. Probably of still greater importance to New Zealand is the possibility of electric smelting of iron and steel, as the country is fortunate in having iron-ore deposits, and the necessary limestone flux, within easy reach of water power.

A recent article in the *Elektrotechnische Zeitschrift by* Mr. A. Van der Haue gives an excellent summary and historical review of the developments of electrical supply on the Witwatersrand in the Transvaal, South Africa. Two stations, one for 2500 kw. and the other for 3700 kw. were erected as early as 1895, but were not very successful on account of the Boer war. In 1906 great interest was aroused by a scheme to develop the Victoria Falls, where from 300,000 hp. to 600,000 hp. is available. But, for financial reasons, the scheme was not carried out, especially as sufficiently large contracts for power could not be obtained in advance to justify the very large outlay of money. It was then decided to erect steam stations since coal is rather cheap in the Transvaal. The erection of new plants was turned over by the English company to the Allgemeine Elektricitäts Gesellschaft, of Berlin. In 1903 there were on the Witwatersrand 307 generators with an aggregate rating of 20,000 kw. In 1909 there were 506 generators with 76,000-kw. rating. The number of motors increased at the same time from 724 to 3022. The increase in the next years should have been still greater. When the new stations of the Victoria Falls & Transvaal Power Co. are finished

it will be able to sell 500,000,000 kw-hr. per year to the different gold mines in the district. According to the Transvaal power act of 1910, 25 per cent of the net earnings of an electric station must be distributed among the consumers, while the station is also obliged to revise the tariff from time to time and to make changes when necessary. The Victoria Falls & Transvaal Power Co. furnished up to January, 1911, electrical energy at 1.5 cents per kw-hr. During 1911 the price was 1.12 cents per kw-hr. On Oct. 1, 1912, it was to be reduced to 1.05 cents per kw-hr. The central stations expect to get a load-factor of at least 70 per cent, while the gold mines expect to save from 16 to 24 cents in the expense for energy per ton of ore.

Turning to the Continent of Europe, it is interesting to observe that construction has begun on a 15,000-hp. water-power plant at Martigny, in the canton of Wallis, Switzerland, to utilize a fall of 5400 ft., making this station the highest-head water-power plant in the world. Special interest attaches to the penstock lines, which are three miles in length. The upper section, which will be under comparatively light hydraulic pressure, is being built of welded steel pipe, 23.6 in diameter. The lower section, which will withstand a hydrostatic pressure of nearly 2500 lb. per sq. in. or 165 atmospheres, is to employ special ingot-pressed seamless steel pipe. The tube sections vary in wall thickness from 1.24 in. at the top to 1.77 in. at the region of highest pressure. The turbines, which will be of the Pelton type and have a total rating of 15,000 hp. will be furnished by Piccard, Pictet & Co., of Geneva. Of some interest is the fact that with the 5400-ft. head available at this plant only about 30 cu-ft. of water per second will be necessary to develop the full 15,000-hp. output of the station.

In speaking of Switzerland, we must remember that it is still the seat of the transmission of energy by direct current. There and in Southern France, some fifteen Thury plants have been installed since 1890, all in constant and successful operation, and one of them, the Montiers-Lyons line, having a 112 miles straight-away transmission at a maximum e.m.f. of 57,600 volts, which it is now proposed to double. An excellent summing up of the situation is made by the *Electrical World* as follows: "The chief objection to the system from a constructural standpoint is the relatively small size in which the units must be built, owing to the difficulties of commutation. Designers have learned from

experience and are now able to produce direct-current machines for constant current for voltages rising to 4000 or 5000, an output of probably 1000 kw. or even 2000 kw. By driving two machines by a single prime mover, units of, say, from 2000 kw. to 4000 kw. therefore become available, giving 8000 volts or 10,000 volts at full load. The constructural features of a Thury station are therefore no longer forbidding. With five or six units one could reach 50,000 volts transmission e.m.f. at 15,000 kw. or 20,000 kw. output, a size adequate for the vast majority of transmission enterprises.

"The constructural inconvenience, on account of the necessity of insulating the generators from earth and from the prime mover, seems to have found a successful solution, as might be expected from our present knowledge of insulating materials. From the standpoint of general energy distribution the system is a peculiar one. It is unquestionably capable of beautiful results in delivering power in a single block. It also presents no difficulties in the way of taking off moderate amounts of power along the line, there being no troublesome transformer at extreme voltage to install. Yet, on the whole, it is much less convenient in general distribution than is a constant-potential system. To make up for the relatively small output and considerable cost of the individual generators, the cost of switchboard appliances, no inconsiderable item in a modern 3-phase station, becomes almost negligible. The generators are disconnected by short-circuiting them and connected in by opening the short-circuiting switch. The whole complex and bulky switching system ordinarily in use, therefore, disappears, and it is at least a question whether the abolition of this serious cause of trouble and expense does not fully make up for the extra cost of the generators themselves.

"When it comes to line construction the series direct-current system has some important points in its favor. Inductive troubles on the line all disappear. There are only two wires instead of three to insulate, and a given insulator will withstand a much higher pressure if it is direct than if it is alternating. Some time ago Thury carried out a series of experiments on high alternating and unidirectional voltages, with the result of showing that on the average the direct voltage necessary to flash over a given distance is double the alternating voltage required for the same

distance. In other words, if a given system of insulators is adapted for an alternating e.m.f. of, say, 50,000 volts, it would carry a much higher unindirectional voltage. Thury's experiments indicated practically 100,000 volts."

The matter comes to a head in the bold project for transmission from the famous Trollhattan Falls, Sweden, to Copenhagen, Denmark. At the well-known tourist resort of Northern Europe, with an available head of 108 ft. and a flow of about 9000 cu. ft. per second, for which the existing installation was planned, approximately 100,000 hp. can be developed; and the plant represents about 75 per cent of that amount. The storage basin is Lake Vanern, the third largest in Europe, with an area of 2150 sq. miles, and an outlet in the Göta River, on which the Falls are situated. The transmission at 50,000 volts from 25 cycle generators has been chiefly to Gothenburg and other cities, but lately the Danish project has come to the front and is attracting world-wide attention, with its 200 miles of transmission. After very careful investigation of all the circumstances and the probable costs of carrying out the generation and transmission of some 20,000 kw. to Copenhagen, the engineering commission found in favor of the Thury direct-current system as against the ordinary 3-phase system. It is especially worthy of note also that the decision was not only in favor of direct current but also of the transmission thereof with a ground return. The comparison was made on the basis of transmitting about 20,000 kw. at fairly steady load into Copenhagen, and the comparison of costs was made between 3-phase transmission of the usual sort at 100,000 volts and the Thury system at 90,000 volts. The advantage of the latter lies in the relative simplicity of the insulation problem, a thing which comes into play only at the extremely high voltages necessary for the economical transport of energy over very long distances. A large and steady load is also a favoring condition of no small importance. The matter of insulation, however, proved the determining factor in the case, and its importance was emphasized by the situation which arises near the receiving end of the line. The Strait of Öresund lies between Helsingborg, the southern terminus of the proposed land line, and the island of Zealand, on which Copenhagen is situated. To cross this strait, nearly 3½ miles wide, cable carrying alternating-current at 100,000 volts was adjudged an utterly impracticable proposition.

It therefore became necessary to plan for a reducing station at Helsingborg, bringing the pressure down to 20,000 volts for transmission under the strait, beyond which it could either continue the relatively short distance to Copenhagen at 20,000 volts, or the electromotive force could be stepped up again if desirable. On the other hand, submarine cable can actually be obtained for 90,000 volts direct current, according to the Swedish engineers, and consequently the energy could be carried through to Copenhagen without any reduction in voltage on account of the submarine work. This matter alone put the alternating-current project at a disadvantage, rendered even more remarkable by the facility with which a grounded line can be used in operating at constant current.

The comparison between the various items of expense in the two plans is a very instructive one. In the generating station the 3-phase equipment had the advantage in first cost, as might have been expected, to the extent of nearly 30 per cent, owing to the necessity of using more units and more expensive units with the direct-current scheme. The 3-phase units were sufficient for the alternating-current plan, while the Thury system required twenty generators in four groups, each coupled to a 5000-hp. turbine. In the line structure the tables are completely turned, the cost of the direct-current line being only about half that of the alternating-current line, not even taking into account the difference in the cost of the cables and the presence of at least one extra transformer station in the alternating-current project. The cables for the 3-phase transmission cost two and one-half times as much as did the direct-current. The grand total for the alternating-current project reached $1,593,000, as against $1,202,000 for the direct-current project advised. When everything was footed up for the rival projects the estimated annual expense for the direct-current transmission was $6.75 per kw. as against $12.43 per kw. for the 3-phase project, to say nothing of the fact that the multiple transformations necessary with the latter would cause it to operate at a lower efficiency, thus yielding a materially small amount of power for the final distribution.

While still in the North of Europe it may be mentioned here that financiers have asked permission of the Norwegian government to harness the Aura and Lilledal Rivers, east of Molde, in the Romsdalen district, Norway. The scheme involves the erec-

tion of a dam 140 ft. high and the transmission of water through a tunnel at Sundalen, where 200,000 hp. could be developed. The estimated cost of the project was $10,000,000 and the scheme if carried out will result in one of the largest hydro-electric power plants in the world. It is also to be reported that it is proposed to develop and utilize the water powers of Finland, by a Belgian company with a capital of $6,000,000.

The Prussian government also comes to the fore with a transmission project of its own to utilize powers which it controls. The region involved is one in the vicinity of Cassel and covers an area more than 60 miles in length and of two-thirds that width. Primarily the network utilizes the water powers on the Weser. The project includes the complete supply of electrical energy to the territory mentioned from three large hydraulic stations united by a 40,000-volt transmission system, which is connected into a 40,000-volt distribution network with nearly a score of transformer stations reducing the pressure to 6000 volts for the secondary distribution. From the hydraulic standpoint the proposition presents some difficulties, inasmuch as provision at two of the three stations has to be made for large variations in head—in one case by providing turbines of special design to work on a head varying from 22 m. to 41 m.; in the other case by the more desperate resort of providing two sets of turbines, one for work under normal ranges of head, the other to deal with cases of extreme high water. In addition to these hydraulic stations, steam reserve is obtained at the municipal electricity works in Cassel and Göttingen, giving a distribution network, with three hydraulic and two steam stations available, and deliberately designed from the start to cover a large territory completely. The project has involved considerable difficulty in working out the details on an economical basis. The complete cost of the installation runs close to $2,500,000. Financially the project had to be considered on the basis of the result, on this investment, of various possibilities of output combined with various degrees of completeness in the initial plan. It turned out, as it usually does in such cases, that the indications favored the carrying out of the complete scheme. It is the complete undertaking, therefore, that the Prussian government is now backing, the first time that it has gone into an operation of this kind on anything like so extensive a scale. It means the general supply of electricity to a large and impor-

tant territory by the organization of just such a network as has become familiar in American practise. The project is based on a classified system of rates for various kinds of service, the list prices varying from about 3.5 cents to about 10 cents per kw-hr., the highest figure being reached for private lighting and the lowest for certain classes of motor service.

With regard to new work in France, the greatest project is the development of the water power of the Rhone River, where a power plant of 24,000 kw. is being erected. The largest part of the energy is to be transmitted at 12,000 volts to Paris, the distance being 430 km. (260 miles). The principal hydro-electric companies of France have combined and formed a syndicate. The total rating of the water-power plants represented in this syndicate is now 575,000 hp., of which one half is sold for lighting and industrial purposes and the other half is used in electro-chemical and electro-metallurgical plants. The total rating of the water powers available in France is estimated as 5,000,000 hp. with a low-water level, and of 10,000,000 hp. with average water level. A great deal therefore remains to be done to utilize this power. Much is expected from the electrification of railways, and many of the French railway companies make experiments, but so far only 10,000 hp. is utilized for electric traction on trunk railroads in the French Republic.

MR. MARTIN (continuing): I believe you are all aware of the fact that this is one portion of my Report on Progress, the other part covering the general progress of the industry having been presented at the first general session yesterday.

The work of power transmission, however, becomes yearly more and more important. At the suggestion of your predecessor, sir, Mr. Doherty, two years ago, I took up the work, dividing the report into two sections, one being devoted to the general advance of the industry, and the other to that part of the work which more directly interests and concerns ourselves.

My report makes special and somewhat extended reference to recent events in New York State. I have been very much interested in listening to the remarks of my friend Mr. Rushmore, who, if I gather rightly, does not altogether approve of the publicity campaign which was conducted through our Public Policy Committee under the auspices and with the approval of this Association. I myself have read a great many of the news-

paper comments upon the work which we attempted to do in educating public opinion in the State, trying to save it from the suicidal financial policy which unfortunately prevails across the line in Ontario. Our work may have been misdirected, and some of the newspapers may not have agreed with us. We have in New York State a Governor who, perhaps, in spite of a few frills and frivolities, is one of the most astute politicians in the United States, and I believe I am correct in stating that the Governor has vetoed the legislation against which we directed our efforts. I think he has his ear to the ground as well as I or Mr. Rushmore, so I do not think we were very much amiss in what we tried to do.

MR. RUSHMORE: Mr. Chairman, may I be allowed just one more word. I wish to apologize for my very poor expression. I most heartily approve of the activities of the Public Policy Committee. To a large extent I most heartily approve of the way they went at it, without any question of the object; and it has been, as Mr. Martin stated, very successful; but if any one will read the editorials in the *Knickerbocker Press* of Albany, one of the most widely read papers in that part of the country, or the other papers of Albany and the country around there, he will see that the people as a whole did not understand even what the National Electric Light Association is; they did not understand that it was an Association of operating companies. He will be convinced by those editorials that the activities on the part of the Public Policy Committee were not understood, and some very unfortunate and erroneous statements were printed in those papers.

I am very sorry Mr. Martin did not understand me, because I am in very hearty accord, from my own point of view, with the activities of this organization. I could not but regret the lack of understanding, and also the lack of appreciation, as expressed by those papers, of the motives and reasons for the activity of this organization. Do I make myself understood, Mr. Martin?

THE SECRETARY: Yes. I now learn to my great pleasure that Mr. Rushmore's reading of the New York press is largely limited to the *Knickerbocker* of Albany, which would hardly give him a correct understanding of New York's opinion as the Empire State. I am very glad to say that I have myself read a great many editorials on this subject. The responsibility was not

mine, although I had, of course, a little to do with it. The Public Policy Committee shouldered the whole job, and did a mighty good job, too, for we turned down the vicious, iniquitous, suicidal and lunatical legislation that was proposed. The press of New York was by no means unanimous in its criticism of the National Electric Light Association, although perhaps it was not quite sure as to our identity, as to the interests represented, or the scope and importance of those great questions which to-day affect practically every central station enterprise in the country.

I am glad to see that my friend Dr. Steinmetz has just come in, because I want to call attention, if I may, Mr. Chairman, to the last part of my report.

Without expressing any opinion of my own, which would not be worth anything if I did, I would like to call attention to the fact that some of the most distinguished electrical engineers in Europe, our Swedish brethren, than whom there are none more competent, have given their approval and support to a proposition to transmit electrical energy from the great Trollhattan Falls, one of the most beautiful spots in Europe. These are being utilized without any protest on the part of the public, such as we happen to have in the case of Niagara, for a 200-mile transmission by direct current in preference to our own familiar standard uniform 3-phase system. There must be some very great, serious underlying reasons which will justify men of their caliber in supporting and putting their names to a proposition of that character, and I can hardly imagine any question which should be of more interest here this morning than the discussion of such a recommendation as that. Without assuming your prerogative, Mr. Chairman, I have already mentioned the name of the gentleman who perhaps might have something to say on the subject.

DR. C. P. STEINMETZ, Schenectady: Mr. Chairman and Gentlemen: I am sorry to say I can not give you any definite information on the subject. It is an economic question, as most engineering questions are; whether the 3-phase system or the high voltage direct current is the more economical. I have not gone over the details of this proposed Swedish long distance transmission closely enough to be able to judge whether the high voltage direct current is preferable in this case. I have, however, gone over a very considerable number of long distance propositions from both points of view, and so far I have not found a case

where the economic advantage would be in favor of the high voltage direct current. That does not prove anything, however, because there may be cases where a high voltage direct current is preferable, and for a very long distance transmission under special conditions, as they exist here in this case, where I believe it is the intention to cross a branch of the ocean by submerged cable, the high voltage direct current would appear to have some advantages.

However, I am not so certain that those Swedish engineers are not making a mistake in adopting the direct current. You see in all such questions there are two things to be considered; first, how much it would cost to operate a 3-phase system, the operating charges and so forth, and second, how much it would cost to operate a high voltage direct-current system, and these can be determined only by practical experience. In this country we know, and elsewhere they know, what they may have to expect with a long distance 3-phase system. We know that nothing unexpected will occur. The relation has been this. The 3-phase system and the direct-current system present the relation between constant potential and constant current. We have had in America a very great amount of experience with both systems, while abroad they have no experience with constant-current systems, because all arc lighting is done with constant potential. My experience with constant current and constant potential is that we never use the constant current except where we must do it in city arc lighting, and I believe the same will be the case with your constant potential and constant current transmission; and I wish to draw your attention to the fact that many advantages of the high voltage direct-current system can be secured in connection with the use of the 3-phase system. You can just as well transmit with a ground return, eliminating all switching devices, by using a constant alternating current, and that furnishes some very great advantages.

I went over one system for Victoria Falls, and there seemed to be a considerable advantage in that case in using a constant alternating current. It gives the advantages claimed for the high voltage direct current, while you get the additional advantages of the ease of control and transformation of the alternating current.

To sum it all up, while I do not believe any engineer would take the stand that nowhere is there any economic chance for a high voltage direct current or a constant alternating current system, so far as all our experience goes, theoretical as well as practical, the arguments are so strongly in favor of a constant potential 3-phase transmission, that without extremely strong arguments in favor of any other system, it is hardly conceivable that a practical engineer would recommend any other system to-day.

MR. ERIC A. LOF, Schenectady: A short time ago I had the opportunity of speaking to one of the engineers who prepared this transmission report in Sweden, and I was told that the problem was a purely economical one, and that they took a stand in favor of the direct system because they could use a higher transmission voltage with direct current, on account of having a submerged cable for three and a half or four miles. It was not possible to get any manufacturers to build cables for more than 90,000 volts direct current, and considerably less for alternating current, so that at that time it worked out to be a gain economically to use the direct current. However, they told me that from an operating standpoint it would be inferior to the 3-phase system. I have spoken to a number of Swedish engineers about the proposition, and every one of them thought that the transmission will never be carried out with direct current, in spite of the fact that it may prove somewhat cheaper.

MR. ARTHUR WRIGHT, London: My experience with the direct-current system is rather old, namely, 1881 to 1889; it is in fact very ancient history. Perhaps some of you gentlemen may remember that we developed a constant-current system for distribution over a town in England called Brighton, where we supplied a few thousand lamps pretty satisfactorily. That, of course, died when the alternating system was developed. Since then I have been connected with this transmission proposition in Victoria Falls, where it was originally suggested that we should use the Thury system, and most of us from the very start thought that it was a very serious experiment for any responsible financial company to undertake, in such a distant country for such a long transmission line, on the ground that at that time no generator unit of more than 400-kilowatts had been run successfully on the Thury system. That appeared to me to be absolutely fatal to any

proposition which involved something like 130,000-kilowatts transmission. To-day I believe, Mr. Thury has successfully raised the unit to something like 1500 kilowatts, but that unit is perfectly ridiculous when talking of some of these transmission powers. It is impossible to talk of dividing 100,000 kilowatts up into units of 1500 kilowatts.

It seems to me that the fatal objection to this system is the difficulty of commutation in units bigger than 1500, though even 1500 is by no means negligible, and the difficulty of commutation seems to have been lost sight of in this Swedish proposition. Nobody seems to have dealt with that real difficulty, the small units that they have to use in connection with this system.

I am afraid I have nothing else to say on the matter, but I quite agree with Dr. Steinmetz about the almost insurmountable difficulties of a direct-current transmission system.

MR. F. B. H. PAINE, Buffalo: As a matter of history, it is interesting and well to remember that the first power transmission in this country was with a constant-current installation in Nevada, made by the Brush Electric Co., and I think it was somewhere about 1888. I can not now remember the size of the units, but they were approximately that of the then largest arc machine, which I presume was about 62,000 candle power lamps.

MR. RUSHMORE: Mr. Chairman, I would just like to go on record with a very sincere expression of appreciation to Mr. Martin for the excellent report he has made, and formally to voice an expression of thanks for the Section.

THE CHAIRMAN: If there be no further discussion, we will pass on the next number, which is that portion of the Prime Movers Committee report relating to water power. This will be presented by the Chairman of the Committee, Mr. Moultrop.

MR. I. E. MOULTROP, Boston: I regret that Mr. J. F. Vaughan, who was chairman of the sub-committee responsible for the bulk of the work of this portion of the report, is not present to present it himself. However I will do the best I can with it.

REPORT OF THE COMMITTEE ON PRIME MOVERS

WATER POWER

In continuing the work of last year your Committee has attempted to gather sufficient statistical information from the various member companies, as well as from outside interests operating water-power plants, to serve as a source of reference for this and subsequent committees, and has taken up only a few special subjects for report. Your Committee has also called upon various manufacturers and independent engineers for information on these special subjects. This information is given in the Appendix practically as received. Some of the subjects printed in the previous reports have been omitted and others revised. The special subjects taken up this year are as follows:

TURBINES

Vertical versus Horizontal Units

The development of the Kingsbury thrust bearing and recent improvements in the design of water wheel runners warrant a revision of last year's report on this subject. The Kingsbury bearing is an oil thrust bearing, similar to the oil pressure type, but with its stationary disk broken up into segmental, babbitted pads, pivoted on their lower side, utilizing the adhesion of the oil to the rotating surface for lubricating the bearing surfaces, and making artificial oil pressure unnecessary. From experience with this device in service in the Pennsylvania Water and Power Co. plant at McCall's Ferry, and from exhaustive tests which have been made elsewhere from time to time, this form of bearing appears to eliminate the troubles and uncertainties which have been found in the past with oil pressure, water pressure, roller and other forms of thrust bearings. The bearing can be installed on old as well as new units, and, in fact, has replaced oil pressure bearings without change in anything but the disks. A full description of the bearing is printed in Appendix A.

Another development in the line of thrust bearings is the combined oil pressure and roller form, which is so designed that in case of failure of the oil pressure the rollers take the

load. Both these types of bearing are to be used in the Mississippi River Power Company's new plant at Keokuk, Iowa.

There is a tendency in the newer plants using vertical units to place the thrust bearing on the top of the generator, so as to support the entire revolving element with the shaft in tension. The advantages of this arrangement are that the bearing is accessible and the shaft free from compressive stresses which require increased diameter.

Recent improvements in design have made it possible to use single runners of high specific speed, in place of multiple runners in vertical units, without materially affecting the cost of the plant.

Runner Wear and Material

In continuing the investigation of deterioration of waterwheel runners your Committee has obtained information and expressions of opinion from various manufacturers and individual engineers, which are given in Appendix B-1, 2, 3, 4 and 5.

The four materials in general use are: Cast iron, bronze, plate steel cast into hubs of cast iron and bronze and cast steel. The choice of material is governed by local conditions of head, water and specific speed, it being a generally accepted fact that the chief cause of pitting is improper design, or conditions of loading for which the wheel was not intended, rather than the material of which the runner is made. Erosion should be distinguished from pitting, as the former is due to the abrasive action of foreign material in the water, rather than to design.

The principal advantage of bronze is its strength and the ease with which it may be cast. Cast steel also gives strength and toughness, but the complicated shapes of buckets, excepting in high-head, Francis type runners, make it difficult to obtain good castings with this metal. Where the conditions do not require great strength or stiffness, as in runners of high specific speed, both cast iron and composite runners are satisfactory and much cheaper. Aside from correct design the question of runner material is still open to discussion.

Testing of Water Wheels

This question was discussed at considerable length in last year's report. To supplement this discussion, a paper by Professor C. M. Allen, of the Worcester Polytechnic Institute, is given in Appendix C.

Your Committee recommends that the subject of continuous measurement of stream flow and wheel consumption in operating plants be further investigated.

Stop Valves

Recent improvements in butterfly valves make it possible to-day to get a fairly tight valve without going to the expense or complication of the gate type. This type of valve can now be obtained in almost any size and for a large range of head.

Another type of penstock valve is a form of balanced needle valve, developed by Mr. R. D. Johnson, of the Ontario Power Co. A description of this is given in Appendix D.

Both the butterfly and the Johnson type of valve have the advantage of being hydraulically balanced in both opening and closing, and require no by-pass.

Relief Valves

The two types in general use at present are the pressure and the governor operated, the former actuated by the variations of hydrostatic pressure in the penstock or wheel case, and the latter controlled by direct mechanical connection to the gate mechanism. These two types are used either separately or together and in certain cases the two principles are combined in a single valve. Recent improvements in the pressure-operated valve have eliminated some of the former objections to this type. On account of recent developments in relief valve design, your Committee recommends a further investigation of this subject.

Stand Pipes and Surge Tanks

Your Committee has not investigated this subject further, believing it to be a matter requiring special study in each individual case.

Penstocks and Pipe Lines

Your Committee recommends for special investigation the subject of wood, steel and concrete for penstocks and pipe lines, with especial reference to reliability, cost and life, and suggests also the subject of protection of such pipe lines against freezing.

NOTABLE WATER-POWER INSTALLATIONS

The water-power development of the Mississippi River Power Co. at Keokuk, Iowa, is an excellent example of the use

of large, single runner, vertical units under low head. This plant is designed for an ultimate installation of 30 turbines of 10,000 hp. each, at the normal head of 32 ft. These units are to develop 14,000 hp., at the maximum head of 39 ft., and approximately 6000 hp. at the minimum head of 20 ft. The runners, which are the largest so far cast, either in this country or abroad, are approximately 16 ft. in diameter and weigh about 130,000 lb. each. Some of these runners were cast in four pieces, held together by cast-steel rings shrunk around the band, while others were cast in one piece. At full load and normal head, each unit will require approximately 2500 cu. ft. of water per second, and will run at a speed of 57.7 rev. per min. These unusual conditions of power and head have resulted in bringing the design of the single runner, vertical unit to a high state of perfection. A further refinement in design is the use of a spiral type of wheel casing, formed in the concrete foundations of the plant.

Another notable development is the Martigny plant in the Canton of Wallis, Switzerland, where a head of 5400 ft. is to be utilized. This is the highest head which has been brought to our notice. The plant is now under construction.

APPENDIX A

THE KINGSBURY THRUST BEARING

BY W. W. SMITH, LIEUT. U. S. NAVY

(*Extract from Journal of American Society of Naval Engineers, Vol. XXIV, No. 4, November,* 1912)

An interesting development in engineering is a thrust bearing invented by Mr. Albert Kingsbury, of Pittsburgh. In this bearing the load is uniformly distributed over the entire surface, and the slippers are free to adjust themselves at slight angles to the collar, so as to glide or skim over a film of oil which adheres to and moves with the collar, the action of a slipper being much the same as that of a single hydroplane. As compared with the usual types, the results which have been obtained with this bearing are remarkable and of great importance. In high-speed bearings a pressure of 500 lb. per sq. in. is being carried, and in low speed 900 lb. Although these pressures are unusually high, they are still far from the safe maximum pressure which can be carried, the factor of safety being ten or more. A test on a turbine-thrust bearing showed that a pressure of about 7000 lb. per sq. in. could be carried without the breaking down of the oil film.

The bearings, both during shop tests and in actual service, have proved entirely satisfactory. The frictional losses and consequently the temperature rise under usual conditions are small, the coefficient of friction being from 0.0008 to 0.003, depending on the size and speed of the bearing, the unit pressure and the character of the oil. The wear has been practically *nil,* because the surfaces are entirely separated by the oil film. No repairs other than periodic examinations have been required.

Kingsbury thrust bearings were fitted on the turbines of the U. S. S. "Neptune," and it was the writer's experience that they gave most excellent results as regards both operation and repairs. In regard to the latter it may be noted that because of the self-alignment of the bearing any mechanic of fair ability can overhaul it without difficulty and with the assurance that it will run properly when assembled, which is of course important.

THE "NEPTUNE'S" THRUST BEARING

The following is a description of the "Neptune's" thrust bearing:

The bearing consists of a body secured to the turbine casing, in which are mounted in spherical seats two rings which carry, also in spherical seats, the slippers which bear against opposite sides of a single-thrust collar, which is held on the shaft by a key and a nut. Each of the slippers, which are of steel with the rubbing surfaces lined with white metal, fits into a recess in the slipper ring which holds it in the correct position, preventing rotation around its longitudinal axis, and is held in its spherical seat by a helical spring held in compression between the slipper ring and the head of its retaining bolt, which passes through a hole in the ring.

Each of the steel slipper rings, which are carried in the spherical seats of the body, is held against rotation and supported by a bolt which passes through a short slot with the spherical lower surface of its head resting on a thick washer on the supporting yoke; this yoke is carried by a transverse bolt passing through lugs on the body.

The cast-steel body consists of a forward part which is screwed into an after part on a diameter exceeding those of the thrust collar and slipper rings, which are contained in the latter. The bearing clearance or "float" is adjusted by screwing the forward part in or out; and, as the after part is divided on top by a longitudinal slot through the threaded portion, the two parts can be clamped in the required position by the transverse bolt, which passes through lugs on each side of the slot. The forward part of the body extends through the casing to which its flange is bolted. Under the flange there are brass liners, made in halves, by means of which the bearing can be adjusted to give the required longitudinal position of the rotor. The body is centered in the casing at both ends.

From a branch of the turbine oil service oil enters the annular space in the forward body behind the slipper ring and passes through the inlet channels into the inside ends of the radial supply spaces between the forward slippers. From another branch oil enters the annular space in the after body behind the retaining bolts of the slippers, and likewise passes through the inlet

channels into the inside ends of the supply spaces between the after slippers. From the supply spaces the oil passes radially outward through the corresponding exit passages in the body, and fills the casing so that the bearing runs immersed in oil, which insures good lubrication and cooling. From the casing oil drains out into the adjoining main bearing reservoir, part of it passing through the space around the shaft and the remainder through the holes in the upper part of the casing.

From the supply spaces oil is drawn under the slippers, which, due to the action of the lubricant, "ride" on an oil film of appreciable thickness, so that there is no rubbing contact between the surfaces. As the slipper ring is free to move in its spherical seat the forces transmitted through the slippers cause it to adjust itself so that the pressure is equally divided among the slippers, and, as each slipper has similar freedom, the forces acting on its surface cause it to adjust itself so that the pressure is uniformly distributed over the surface. Therefore, the self-adjustment of the bearing automatically distributes the pressure uniformly over the entire surface; and, as there is an abundant supply of oil introduced between the surfaces, the unit pressure on the bearing surface is with safety carried much higher than usual.

The pressures acting on the surface of a slipper are, of course, not equal. They are greatest at a point slightly beyond the center in the direction of rotation, and become less as the edge is approached in any direction. With relation to the surface, as a whole, however, the pressures are balanced and, considering the action of the lubricant, are uniformly distributed.

The oil drawn under the leading edge of a slipper escapes from the three remaining sides, the major part of it passing out under the following edge. Therefore, the thickness of the film is greatest under the leading edge and least under the following edge. This difference of thickness of the film causes the slipper to stand at a slight angle to the surface of the collar, and, so to speak, it "rides" on the film in a position which is required for the proper action of the lubricant. This is similar to the action in a cylindrical bearing, where the greater thickness of the film on the leading side causes the journal to run slightly eccentric to the bearing. However, due to the journal and bearing having approximately the same curvature, the action of the lubricant is

not as perfect as in the case of the slippers with plane surfaces. In the usual types of thrust bearings, where the surfaces are held rigidly parallel, the action of the lubricant is still less perfect, which accounts for the low unit pressures to which they are limited.

The "Neptune's" bearing, which has been described, illustrates in a general way the mechanical features of all Kingsbury bearings. The details are varied somewhat to suit the conditions, but the principle of construction remains the same. The bearing * * * is used to support the rotor of a large water-wheel generating unit. It will be noted that the slippers have plane surfaces which rest on spherical seats, which in this case are convex to the slipper. The slipper seats are provided with ledges and liners by means of which the vertical position of the rotor can be adjusted. Each slipper can be adjusted independently and removed radially as shown. The center of support for the slipper is slightly beyond the geometric center of the surface in the direction of rotation, and corresponds with the theoretical center of pressure. This construction gives greater freedom to the slipper and slightly reduces the co-efficient of friction. Oil is admitted to the reservoir formed by the bearing casing, and passes out through an overflow pipe. * * * The bearing therefore runs in an oil bath and is subject to continuous circulation, which removes the heat. In this type of bearing, where the thrust is always in the same direction, only one set of slippers is used. This type is also used in turbines and other horizontal machines, where the thrust is always in the same direction. In marine turbines and other machines where the direction of the thrust changes, slippers must, of course, be provided on both sides of the collar, as shown in the "Neptune's" bearing.

APPENDIX B-1

WATER-WHEEL RUNNERS AND RUNNER MATERIAL

(*From Allis-Chalmers Company*)

Supplementing our acknowledgment of your letter of February 5, we will outline roughly the general results of our experience in connection with the use of various materials for runners under the entire range of heads met with in connection with reaction units.

In the first place, we wish to emphasize the fact that the construction chosen for any particular conditions is primarily fixed by the manufacturing conditions. This is true in practically all cases, except in rare instances when the water to be used carries a heavy content of acid, alkali or air.

We are attaching hereto a data sheet (Fig. 7) which will serve as an excellent basis for taking up various constructions. You will note that this data sheet is made up showing the characteristics of runners in actual service under various heads. The shaded portion is drawn in as indicating roughly what we believe to be the limits of good practise. When this limit is exceeded it is usually done for some very special reason and the case is to be considered a special one, but within these limits the question of suitable materials can be discussed in detail.

Starting in with the lower heads, that is, say up to 50 ft., the plate steel vane construction of runner has shown excellent results in durability and strength. For the larger sizes, that is, for runners from 6 to 7 ft. in diameter at inlet, it is usually necessary to resort to solid cast runners purely on account of strength of construction.

There are numerous instances of failure of plate-steel, cast-iron and even bronze runners under these low heads, but such failure, except in the case of excessive chemical content in the water, is usually directly traceable to defective design. It seems that when the runner is not properly designed so far as the water passages are concerned it makes little difference as to what material is used, failure taking place in a comparatively short time in any event.

For the higher heads, that is, from 50 to 150 ft., failure due to improper design is correspondingly more rapid than for the lower heads, imperfections showing up much more quickly. For these conditions the plate-steel vane type of runner is entirely suitable, except in connection with larger sizes, where the feature of strength makes a solid cast runner a necessity.

For the usual type of installation under heads less than 100 ft. a high-speed type of runner is the rule, and the complicated form and extreme proportions of such high-speed runners make the use of cast iron more or less questionable, shrinkage setting up indeterminate strains and warping the vanes to a greater or less extent.

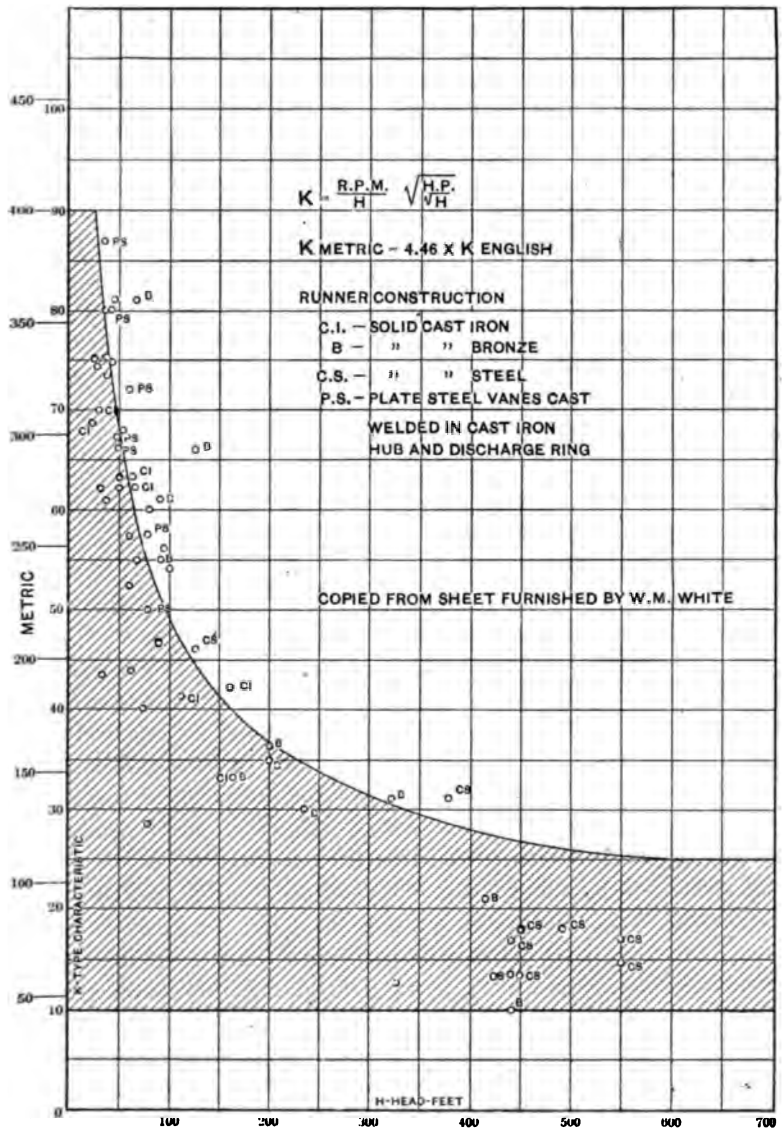
$K = \frac{R.P.M.}{H} \sqrt{\frac{H.P.}{\sqrt{H}}}$
K METRIC = 4.46 X K ENGLISH
RUNNER CONSTRUCTION
C.I. — SOLID CAST IRON
B — " " BRONZE
C.S. — " " STEEL
P.S. — PLATE STEEL VANES CAST
WELDED IN CAST IRON
HUB AND DISCHARGE RING
COPIED FROM SHEET FURNISHED BY W.M. WHITE
METRIC
K-TYPE CHARACTERISTIC
H-HEAD-FEET

FIG. 7

For the higher heads, that is, up to 500 or 600 ft., there are numerous instances of runners in actual operation cast solid of bronze, cast iron and cast steel. The better casting can be secured in the case of the bronze runner, closer adherence to design and smoother water passages being obtained. While the bronze is rather high in first cost still the scrap value of the runner offsets this greatly.

In general, for high heads we very much prefer bronze runners, as they possess advantages from a manufacturing standpoint, as outlined above, due to the fact that they offer greater resistance to oxidation or rapid erosion, due to the presence of excessive air in the water. Cast-iron runners are in use under very extreme conditions of head and capacity and show up very well. This is true likewise of cast steel, though there is some preference for this material, on account of the less likelihood of cracks due to shrinkage strains or shocks which the vane might receive in erection or in operation. We have one particular example of this where there is a large cast-steel runner, head approaching 400 ft., that has been subjected to the shock of passing rocks of considerable size. As a result the vanes are scored deeply in places and it seems questionable whether cast-iron vanes would have stood up.

The attached curve sheet (Fig. 7) indicates not only actual installation and a rough limitation of speed characteristics, but each installation is marked, indicating the runner construction used. No attempt has been made to differentiate between small runners and large runners and there are several instances of plate-steel vane construction for high heads where the runners used were extremely small and consequently are no criterion of practise in connection with units of appreciable size. This is true of installations 22, 49, 29, 3, 20, 36 and 24.

The exception mentioned in the first part of this letter in connection with the use of bronze is a question of chemical analysis of conditions to be met. There are numerous compositions of acid and alkali-resisting bronzes and no general statement can be made concerning material to be used. Some grade composition of bronze is usually selected for such extreme conditions, and while the usual runner bronze corresponding to United States Government standard is very satisfactory, as a rule, still considerable divergence from this composition is desirable for particular instances.

We trust that the foregoing, together with the data contained on the attached sheet will be of assistance to you. * * *

Yours very truly,

ALLIS-CHALMERS COMPANY,

W. M. White,

Hydraulic Department.

APPENDIX B-2

IN REGARD TO WATER-WHEEL RUNNERS AND RUNNER MATERIAL

(Letter from I. P. Morris Company)

I have your letter of the 19th inst., in reference to the erosion of water-wheel runners.

I would refer you to an article which I wrote for the *Engineering Magazine,* March, 1910, which goes into the question of erosion in more or less detail, and gives the operation of the Great Western runners. Probably this article will give you some information on the points which you desire. I may say in this connection that my experience since 1910 has not altered my view in connection with erosion.

Since then, however, while bronze is still used for very high heads, iron is being applied to higher heads every year. In other words, five or six years ago iron runners were applied only to very low heads, while to-day we do not hesitate to apply them to heads up to 150 ft.

Cast-steel runners have also been used for high heads, and the principal objection to their use is that it is impossible to tell whether the castings are homogeneous or not. A small blow hole in the casting, discovered during the machining may be found to open up, inside of the hub, where it joins to the vanes, into a considerable cavity. Such cavities have been found in runners built by nearly all of the steel foundries.

It is possible to secure a much more homogeneous casting in iron than in either steel or bronze, and for that reason there is a certain amount of assurance in making iron runners that the sections of metal in the casting are as called for on the drawing, and that the resulting stresses are as calculated.

There is one subject in connection with the design of runners upon which, I think, the opinion of various engineers and water-

wheel builders would be of considerable value at this time, and that is the matter of built-up runners; i. e., runners in which plate-steel buckets are used in conjunction with iron or bronze hubs and retaining bands.

The only recommendation for the built-up runner is its cheapness. I have, however, been adverse to its use, owing to the experience which certain companies have had with its failure. I recently examined a built-up runner made in France, in which the buckets were made of plate steel and the hub and band of bronze. This runner was of low specific speed type with short vanes, and had been in operation for a number of years under a head of only 130 ft. The bronze was badly pitted and a number of the vanes had shaken loose from their sockets.

It would seem to me that, in casting the hub and retaining band around the plate-steel buckets, when the hot metal comes in contact with the buckets the metal would be instantly chilled and would not form a bond. A very minute examination would probably show a small void between each plate-steel bucket and the metal of the hub and band.

If a built-up runner be properly designed, probably erosion would not develop for a considerable period, but once started, it would do so at an accelerated rate, and the conditions would undoubtedly be aggravated by the fact that two different metals are used in the runners, permitting galvanic action.

In high specific speed wheels, such as are used for low heads, in which the depth of the wheel buckets is very great, it has been the experience of some engineers that the buckets shake out of the hub and retaining band. This probably is the result of vibration. Although it is true that it is possible to make a mechanical balance of the runner in the shop, at the same time it is impossible to make all of the areas through the vanes the same, and owing to this fact the hydraulic conditions are unbalanced. As this unbalance is equivalent to a mechanical unbalance, the vibration of the runner may be considerable. The vibrations set up by this hydraulic unbalance may, in time, shake the plate-steel buckets from their sockets, especially as there is no metallic bond between the buckets and the rim and hub.

For high specific speed wheels undoubtedly the best construction is based upon the solid iron casting. In comparing a runner with plate-steel buckets with a runner which is a solid

iron casting undoubtedly the iron runner is the stiffer, when the factor of safety for the stress in the vanes is the same for both cases. The allowable stress in the steel would probably be four times the allowable stress in the iron. The modulus of elasticity of cast iron is one-half that of steel; consequently the deflection of the plate-steel buckets would be at least twice that of the iron vanes. Any advantage, therefore, which could be gained by reducing the thickness of metal by the use of plate-steel buckets would be offset by the increased deflection and consequent distortion of all the areas of the runner.

If erosion has developed in high specific speed built-up wheels the grip which the hub and retaining band have on the plate steel buckets will be considerably lessened, and the life of such a runner will not be very long.

I understand that the use of low specific built-up speed runners is common practise in Europe for high head, but during a recent talk with one of the foreign engineers he stated that these built-up runners have not been so successful for the high specific speed type.

Probably the principal claim for the use of built-up runners by those who manufacture them is that it is possible to get a more even spacing of the wheel buckets than with solid castings. In the case of the large cast-iron runners which we built for the Mississippi River Power Co., which have an extreme diameter of 17 ft. 10 in., the areas through the wheel buckets do not vary more than one per cent from those called for on the drawing. In other words, it is just as easy to accurately space the cores in a mold as it is to accurately space the plate-steel buckets in a mold.

Summing up the foregoing, I may say that the reason for erosion and the best metals to resist it are pretty well understood by engineers, but there seems to be a considerable amount of agitation recently in reference to the advisability of using built-up runners. I find that there is great opposition to their use from a number of prominent engineers, and personal investigation would show that the only feature which recommends their use is low first cost.

Yours very truly.

I. P. Morris Company,

H. B. Taylor,

Hydraulic Engineer.

APPENDIX B-3

WATER-WHEEL RUNNERS AND RUNNER MATERIAL

(Letter from Viele, Blackwell & Buck)

Referring to your letter of January 23, regarding the use of different metals for water-wheel runners, I would say that for our own information on this subject we installed runners of bronze, cast steel and cast iron in the power plant of the Great Western Power Co., at Big Bend, Cal. These units have been running almost continuously at high load-factors for four years, each delivering 11,000 kw. under a head of about 440 ft., and at a speed of 400 rev. per min. There are two runners of bronze, one of cast steel and one of cast iron, with an extra cast-iron runner as a spare part. During the first year and one-half of operation, with a low temporary dam, a great deal of sand and gravel passed through all the water wheels, more, however, going through one unit than the others on account of the location of its penstock near the end of the header. The runner of this unit was of bronze and was cut out as much as 3/8 in. in places. It was repaired by being turned down and having rings added in the clearance spaces. No other repairs have been required and recent inspection shows all of the runners to be in good condition. There are a few nicks on the edges of the buckets of the cast-iron runner. There is no pitting on any of the runners. This experience confirms our belief that pitting is usually not due to the materials employed in the castings, but to poor water wheel design, particularly as some of the worst cases of corrosion we know of have occurred in bronze runners.

Careful tests made on the different Big Bend water wheels showed them all to have high and practically equal efficiencies.

In general it is evident that runners of bronze and cast steel are less liable to breakage than cast iron. Bronze and cast iron have the advantage of giving smoother and better castings than steel and are much less expensive to finish to a proper surface.

Our data show that there is little choice between bronze, steel and cast iron so far as cutting by sand is concerned. Other things being equal we prefer bronze runners for mechanical reasons, but, of course, cast iron is very much cheaper.

Yours very truly

VIELE, BLACKWELL & BUCK,

F. O. Blackwell.

APPENDIX B-4

IN REGARD TO WATER-WHEEL RUNNERS AND RUNNER MATERIAL

(*Letter from Wellman-Seaver-Morgan Co.*)

Referring to your inquiry in regard to my views on the question of runner materials, * * * there are, of course, a number of questions involved which are closely related to the problem of the selection of the proper material for runners under various conditions. The type of construction has an important bearing on this question and in present-day practise this seems to be divided quite sharply into two methods; one the solid casting made from cores, and the other the built-up runner in which the buckets or vanes are either cast separately or stamped from steel plates and the hub and band afterward cast onto them.

The built-up runner, I believe, is the older of these two types of construction, in this country, at any rate. It was at one time almost universal practise on ordinary work to cast the buckets of iron and then set them up in a mould and cast the hub and band on them. This method is still used by some of the less progressive builders. It has manifest disadvantages and a great deal of trouble has resulted from runners made in this way. There is no weld formed between the buckets and the hub or band, and, inasmuch as the cast vanes are necessarily rather thick and cannot be deeply imbedded in the hub or the band, that is, in relation to their thickness, the joints have not the necessary strength to give satisfactory results, except for low heads. If the torque on the wheel is high or if much vibration is present, these wheels soon shake themselves to pieces.

Another method of making a built-up runner, which is widely used in Europe and which is coming into use in this country, consists of stamping the buckets from steel plates and casting the hubs and bands onto them afterward, using either cast iron or cast steel for the latter purpose. These wheels seem to give much better satisfaction, due principally to the fact that the buckets are thin and can be more securely embedded in the hubs and bands, and also to the fact that the buckets are not as rigid as they are when cast. There is more spring to them and they are able to absorb sudden shocks without straining the joints to the extent that would be the case if the buckets were

rigid. This spring, however, is a serious defect unless kept within proper, limits, and hence these wheels are not applicable to high heads or to large sizes even under low heads.

The question of solid runners *versus* built-up runners, provided the latter are used within their legitimate field, really is of more importance to the manufacturer than it is to the purchaser. It is claimed that built-up runners are cheaper to make than solid runners, but in my opinion this is open to question. It is also claimed by some that the built-up runners are more accurate. I claim to have no experience in making runners with steel-plate vanes, but it seems to me that there are difficulties in their manufacture which make this claim also questionable. The plates have to be heated in order to stamp them, and it seems inevitable that they warp some in cooling. On the other hand, the solid runner is made from a set of cores all made in the same core box, and, therefore, as nearly alike as they can possibly be. The core box can be accurately checked up from the drawing room layout of the runner and should, therefore, be in strict accordance with the design. There is, of course, an opportunity for some slight inaccuracies in the setting of the cores, but in practise they seem to be negligible. In any event such inaccuracies cannot affect the openings between the buckets. They can affect only the thickness of the buckets, which is a matter of much less consequence than errors in the openings. The body of the core forms the space between the vanes, and if the cores are all alike the spaces are bound to be all alike, even though the cores are not accurately set.

On account of the fact that the structural strength of the built-up runner limits it to small sizes and low heads, it is in competition chiefly with solid cast-iron wheels. The question of relative durability is one that seems to me more important than any other. Plate-steel vanes are very much thinner than cast-iron vanes, and the same amount of wear will reduce the strength of the built-up wheel much more than it will reduce the strength of the solid wheel. I do not know that there are many data on this point, but it is a pretty well established fact that rolled steel does not last as long in water as cast iron. For example, the case I mentioned to you the other day in regard to the wheel at Columbus, where the runner, which is of a very high specific speed, operating under bad draft tube conditions,

ıowed no pitting whatever, whereas all of the forged-steel parts ˙ the wheel are badly pitted. I do not feel that I am sufficiently ›sted to take a more definite stand on this point, but I think it one that should be thoroughly investigated.

For high-head work and for large runners under low heads e built-up type is usually out of the question. Solid castings ·e necessary for structural strength and the only problem hich remains to be considered is that of material. For :ample, the runners which we made for Keokuk could not ›ssibly be made on the built-up plan. In transmitting the rque to the hub the vanes act very much like cantilever beams, ıd it is necessary to make them very heavy and to have a very ıbstantial connection between the vane and the hub. These ınes are 6 in. thick at some points and taper to a thickness of ›out ¾ in. at the discharge end, and even less at the entrance lge. It is quite obvious, of course, that plates of uniform ickness could not be applied to these conditions.

The commonest material for runners under high heads is ıquestionably bronze, but whether this should properly be so a question which, to my mind, is open to considerable doubt. here have not been enough experiments made to determine hether there is any good reason for it or not. It is largely a atter of precedent. I am inclined to believe the use of cast eel, and even cast iron, for high-head work will increase in ıe future and that bronze will be used less and less all the me. There are, of course, large runners under very large :ads, which could probably not be made out of cast iron because ıe stresses would be too high, but, excepting such cases, the ıief argument against cast steel and cast iron is based on the ıestion of durability.

Deterioration of runners is due to two causes; namely, pitng, which is a chemical action, and cutting or wear, which :sults from the presence of abrasive material in the water. In :spect to cutting, bronze is probably not as durable as either ıst steel or cast iron, but in respect to pitting there is no question ıat bronze is more durable than either of the other materials. ˙ a tendency to pit exists bronze is the best material to resist it, ıd the problem thus reduces itself to a question of whether run- :rs for various conditions can be designed without a tendency pit. If this can be accomplished, and there is certainly every

reason to believe that it can, within certain limitations, of course, then bronze loses its chief advantage.

I think it is generally agreed that pitting is due to eddy currents or hydraulic disturbances in the runner. If the runner is so designed that water flows through it smoothly and remains in contact with the surface of the vanes there will be no pitting whatever, but if the design is such that the stream of water breaks away from the surface of the vane then pitting is likely to occur. This is true of propeller blades or any other metallic bodies subject to the action of water at high velocities. I have seen a great many discarded propeller blades, but have never seen one that was pitted on the front surface, that is, the surface against which the thrust acts. They are always pitted on the back side, indicating that the current of water whips over the edge of the blade, leaving a cavity on the back side. The same thing occurs on water-wheel runners. If they are pitted on the discharge end of the vane the pitting is almost invariably on the back side, that is, the side toward the direction of rotation.

Inasmuch as pitting is due to disturbances in the runner it is natural to expect it should be very closely related to the efficiency of the runner, and this seems to be the case in practice. The higher the efficiency the less tendency there is to pit, but this does not necessarily mean that the rule is invariable. It is possible for a wheel of generally high efficiency to have some small imperfections of design which would cause some part of the vane to pit, but would, nevertheless, not be of sufficient importance to lower the total efficiency of the runner very perceptibly. High efficiency is not an absolute guarantee against pitting, but it is true that the higher the efficiency the less likely it is that pitting will occur.

I have some runners in mind showing about 88 per cent efficiency under test which, nevertheless, began to pit along the entrance edge soon after they were put in operation. Analysis of the design showed that the entrance angle was not correct, but the error was not sufficient to have much effect on the general efficiency of the wheel. If the entrance angle, however, had been correct it seems quite probable that these wheels would have shown several per cent better efficiency.

It is generally recognized that there is an important relation between specific speed of the runner and the question of pitting.

Both practise and theoretical analysis, however, tend to show that in this respect it is merely a question of efficiency. Most of the wheels of high specific speed which have been running long enough to show any results are of a less efficient type than wheels of lower specific speed. It is to be expected, therefore, that such wheels will show some deterioration. This is particularly true when the general characteristics of the relative efficiency curves are considered. At the present writing it has been found possible to develop wheels of high specific speed which show just as good peak efficiency as do wheels of lower specific speed, but the full gate efficiency is lower and the part gate efficiency is very much lower. Consequently the average efficiency over the ordinary range of operating conditions is lower and it would not be unnatural for these wheels to deteriorate more than the others. The tendency in the development of runner design, however, is to raise the specific speed without sacrificing the efficiency. It is quite probable that in the future it will be found possible to design wheels of high specific speed which will be just as durable as wheels of low specific speed.

The relation of efficiency to durability also involves a very important relation between the durability of the wheel and the conditions under which it is operated. The efficiency of any wheel at low gate opening will fall off considerably, thus indicating, aside from theoretical considerations, that the hydraulic conditions in the runner are considerably disturbed, this creating a tendency to pit. Even the most efficient wheel, if operaated too constantly at low gate opening, is likely to show some pitting if the head is at all high. This is a point which should be brought more prominently to the attention of power-house operators. The average operator is very much inclined to keep more machines in operation than there is any necessity for. This, of course, results in some, or all of them, running at a lighter load than should be. No power plant can be intelligently operated without giving due consideration to the characteristics of the wheels which are being used. If they are wheels of high specific speed they should be kept as closely loaded as possible to the point of maximum efficiency. If they are wheels of lower specific speed it is not necessary to operate within such close limits. This, of course, indicates that the wheel of high specific speed is not adapted to a plant with only a few units, unless the

load is practically constant. If there are wide fluctuations of load this wheel is not adapted unless there are enough units in the plant to permit easy adjustment of the load by cutting in and cutting out additional units.

Very truly yours,

WELLMAN-SEAVER-MORGAN CO.,
Chester W. Larner,
Hydraulic Engineer.

APPENDIX B-5

IN REGARD TO WATER-WHEEL RUNNERS AND RUNNER MATERIAL

(Letter from the Ontario Power Co., of Niagara Falls)

To answer your inquiry of January 23, relative to the best material for turbine runners, it is my opinion that bronze will ordinarily give the longest life with the greatest freedom from pitting, and is the best material to use where the cost is not to be considered. There are many qualities of bronze, and this statement should not be understood as applying to any and every grade, but rather, in order to obtain the best results, to a dense, tough, malleable bronze. Pitting is not a matter to be entirely overcome by the material of the runner; correction of this should rather be looked for in the design of the runner.

You open up a very debatable question and the information obtained should not be used over too extended a field. My opinion as given applies particularly to runners for from medium to high heads.

Yours very truly,

ONTARIO POWER CO. OF NIAGARA FALLS,
V. G. Converse.

APPENDIX C

EFFICIENCY TESTS OF WATER-WHEELS AFTER INSTALLATION

(By Professor C. M. Allen, Worcester Polytechnic Institute)

The majority of water-power plants found in the Eastern Atlantic States, New England and the Province of Quebec, Canada, are medium or low-head installations, as compared with the high-head installations of the Pacific Coast States, and only the method of testing water wheels for efficiency operating under medium or low heads will be discussed in this paper.

Holyoke Tests

The writer believes that the individual runners should first be tested at the Holyoke flume, unless the same type has previously been tested there. The runners should be set up and tested as they are to be operated after installation, that is, with their own guide vanes, gates, etc.

The Holyoke tests of a runner furnish a deal of valuable information which should be known before rather than after installation. It is a well known but often overlooked fact that a poor runner can never be made a good one, even though installed in a good setting, and, on the other hand, the performance of a good runner can be seriously affected by a poor setting. A Holyoke test of the runners of a unit, therefore, predicts what may be expected of them after installation; if, when given a good setting, they do not come up to this expected power and efficiency, the blame should not be put upon the runners but upon the setting. (The setting includes the water ways to the runner, the casing surrounding it and the draft tube or tubes and the tail race conditions surrounding them.) In other words, the responsibility of performance is thus more definitely located. There have been cases where three or four different runners, sometimes of different makes, were installed in succession in the same setting in order to fulfill guaranteed power and efficiency, but to no purpose. The trouble was in the setting.

Testing After Installation

Although the Holyoke tests are exceedingly valuable, yet they do not take the place of efficiency tests made upon the water

wheels after installation; and if but one test can be made, the test after installation should be selected, as this test should show just what the wheels can do, both as to power and efficiency at various gate openings and under various speeds, in a plant under actual running conditions. If the wheels are installed in a hydro-electric station there are two methods available for making efficiency tests, the first using the electrical generator to determine the horse power input and the second some form of friction brake to determine the horse power output. Of course, water measurements should be made in the most reliable manner. At the present day there are several methods of measuring water which can be used in connection with water-wheel tests and the method to be chosen is determined by the conditions in the individual plant. Water measurements will be taken up later.

An electrical test properly conducted should be sufficiently accurate and reliable in determining the output of the wheels. The reason for making brake tests in hydro-electric stations has been, in a good many instances, to settle disputes between the hydraulic power and electrical interests, relative to the guaranteed operation of the plant. A large number of water-wheel builders in this country are not willing to abide by the results of an electrical test unless the wheels show up to the guaranteed power and efficiency under such tests. The generator manufacturers are also unwilling to assume that the generators are low in efficiency or that their testing apparatus is unreliable. The use of the brake for determining the actual horse power output of the wheels at the generator coupling is entirely satisfactory to all parties concerned for the simple reason that the apparatus is very much less complicated and more universally understood.

Moreover, the accuracy of the brake can be determined on the ground, while under test, as the calibration of the machine can be made at that time, and there is no possible chance for a serious error. In other words, the brake test is the simplest, most accurate, and most direct method of measuring power and is universally recognized as the standard. In making electrical tests there are many more chances for errors to creep in than in making brake tests. Ordinarily several electrical instruments are needed, which should be carefully calibrated before and after tests. These are liable to become changed in transit to the station. Many times, after being calibrated, they are used

under different conditions of temperature, magnetism, connection, etc., and the total results are liable to error because of the number of instruments to be read, thus bringing in errors which may be more or less cumulative.

There is another reason for making brake tests rather than electrical tests at the present time, which is a purely human one. No one but an electrical engineer or some one with considerable electrical engineering training can understand the method used on a complete electrical test, while every one interested in the plant can understand the method of a mechanical brake test. All parties concerned can have their representatives on the ground to check up measurements on the brake and calibrate it exactly as it is used under running conditions, and so get with certainty the output of the wheels which is to be delivered to the generator. Furthermore, in order to determine the complete characteristics of the wheel under varying gate openings and with any considerable variation in speed, it is not always practical to use an electrical generator to furnish the load.

Up to within a few years it was impossible to make brake tests of very large units, but to-day the Alden absorption dynamometer has been developed so that it is possible now to successfully absorb up to 5000 hp., and there is no mechanical reason why the same brakes could not be designed to hold even as high as 10,000 hp. A complete description of the Alden dynamometer and its use in connection with water-wheel testing can be found in the Transactions of the American Society of Mechanical Engineers, Volume 32, published in the year 1910. This paper not only describes the brake but gives results of various tests of wheels, showing good and bad settings. It also gives tests of vertical wheel installations where large bevel gears were used, showing the efficiency of these gears. Since this paper was written several other tests have been made to determine the efficiency of large bevel gears, and the results of the later tests check those mentioned in the paper. It was found that in a unit developing something over 1000 hp., using large cut-steel bevel gears, an efficiency of about 97 per cent for the gears was obtained. From all tests made it would seem that a properly designed and constructed pair of bevel gears is the most economical method of transmitting power from a vertical to a horizontal shaft.

Water Measurements

There is to-day considerable discussion concerning the most accurate method of measuring water. Some engineers claim the weir to be the most accurate, others the current meter, and still others some form of Pitot tube. It is the writer's opinion that any of these methods is sufficiently accurate for making efficiency tests of water wheels provided conditions are favorable and the instruments in all cases are properly handled.

The Weir

The weir gives a very satisfactory means of accurate water measurements if the conditions at the plant allow for its being properly installed. This unfortunately is seldom the case in plants that have been built without any plans for such installations. If when a new plant is installed the idea of making efficiency tests is kept in mind a very satisfactory weir could be arranged for in connection with the cofferdam below the tail race. Then when the plant is started a complete set of weir tests can be run off on as many units as desired before taking out the cofferdam; or, as in some plants, there might be installed permanent arrangements for measuring water by the weirs. This, of course, would make it possible to take efficiency tests of the plant from time to time to check up the performance of the wheels, and this is to be strongly recommended.

Current Meter Measurements

The current meter, if properly rated and handled, both during the rating and in use in the field, is a reliable and sufficiently accurate instrument for measuring water, either before or after discharge through the wheel, provided there is proper location and condition of water. Sometimes the best place for current meter work is in the open flume above the wheels. If measurements must be taken below the wheel it is advisable to use the meter in a uniform section of the tail race and where the water conditions are as smooth as possible. It is sometimes necessary to put in some form of rack to straighten out the crooked water which is always found immediately below the draft tubes.

The Price current meter is considered reliable and accurate, but in water that is considerably agitated it will give excessively high readings and should not be used. Meters of the Fteley or Haskell type would be more accurate under these conditions.

There is at present considerable discussion on this subject. It is of great importance that the current meter be carefully rated and used by an experienced operator. (See paper written by B. F. Groat in Proceedings of the A. S. C. E., December, 1912.)

Pitot Tube Measurements

There are a good many plants so installed that it is impossible to measure water either by the current meter or by the weir, and yet some form of Pitot tube inserted in the penstock, f properly handled and rated, would give accurate and reliable esults. In the past few years, the writer has had occasion to ate and use a great many Pitot tubes of various designs and nakes, and has come to the following conclusion concerning heir use:

Under no circumstances should the Pitot tube be used to neasure the actual velocity of water in a pipe line or open anal unless the particular instrument has been carefully rated n moving water at approximately the same velocity in which t is to be used. What is called "still water" rating of Pitot ubes is not the same as moving water rating by a considerable er cent. A pair of Pitot tubes which can be reversed at any ime, while in use and while rating, has distinct advantages over iny other form. An instrument made up of two Pitot tubes, one facing up stream and the other down, that can be reversed and yet show the same deflection for the same velocity, makes an exceedingly valuable check on the work in the field, as Pitot tubes very easily become fouled by foreign matter floating in the water. If the instrument can be reversed to show the same deflection, confidence in it is assured. The writer believes that it is possible under ordinarily good conditions and with experienced operators to determine within 2 per cent the actual amount of water flowing, which is sufficiently accurate for all commercial requirements. This has been done many imes where the same water was measured through a Venturi neter and by a standard weir and with various current meters.

'he Care and Operation of Water Wheels

It is almost universally conceded that among prime movers e water wheel gets by far the least attention in regard to ; operating conditions. This, of course, is entirely wrong, d while perhaps the wheel may not need the close attention that

the steam engine receives it should be carefully inspected, in most plants at least, once in two weeks to make sure that the inside bearings are in proper condition, that the shaft is in line, that the gates are in good working condition, that all trash is kept out of the wheels, etc. Where wheels are standing idle certain portions of the year, they should be thoroughly cleaned

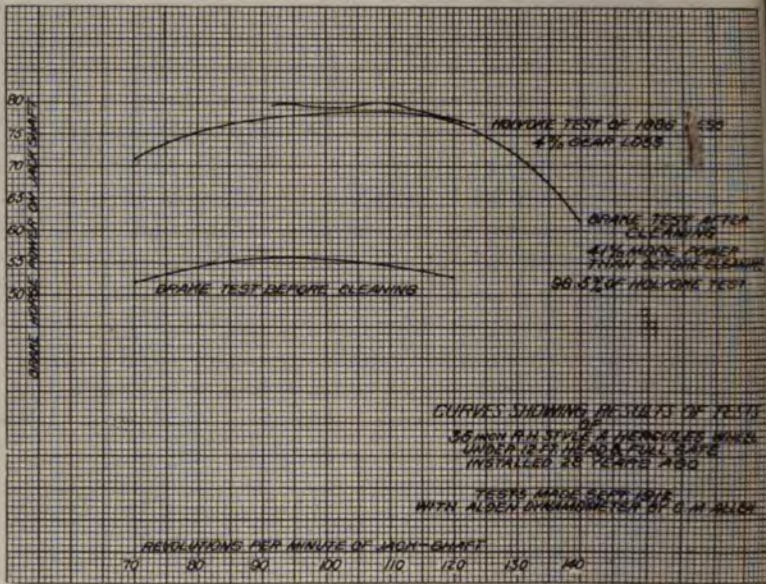

FIG. 8—CURVES SHOWING RESULTS OF TESTS OF 36-IN. R.H. STYLE A, HERCULES WHEEL UNDER 12 FT. HEAD AND FULL GATE—INSTALLED 28 YEARS AGO.

before starting up. Tubercles or barnacles will form on the runners and on the guide vanes or gates and seriously lower the efficiency of the unit.

The accompanying sheet of curves (Fig. 8) will give graphically the effect of cleaning on the power developed by a water wheel after having stood idle for some months. While this may be a very bad case it will show what can happen.

If it is impossible to keep a daily record of the amount of water used by the wheels and the power output in a given plant, it is strongly recommended that occasional tests be made, in

order to determine whether the plant is operating under its p efficiency. A good many times the difference between the running efficiency of a plant and the amount it would properly kept up is enough to make the difference betw good-paying proposition and one that does not pay at all.

APPENDIX D

JOHNSON TYPE PENSTOCK VALVE

(Letter from the Wellman-Seaver-Morgan Co.)

Referring to the matter of the Johnson type penstock v about which you were asking, I enclose herewith two blue of our drawing 47968 (Fig. 9) which show the general struction of a horizontal valve of this type.

These valves are very simple both in construction and o tion. All the parts are of circular form, which makes especially adapted to high heads, owing to the fact that the mum strength of the material is developed without tenden deform, which is one of the great difficulties encountered i design of gate valves.

This valve is perfectly tight when closed, and is re operated by hand or by electric control, either locally or fr distance. There are no sliding contacts under heavy pre and the valve is much more reliable in operation than any type of valve of which we know. It is needless to point ou disadvantages of gate valves, particularly in large sizes and high heads, as all operators who are familiar with them the troubles which are experienced.

This valve consists of a moving plunger of the needle having two pressure chambers, one to close it and the oth open it. The valve is closed by admitting penstock pressu the large chamber and exhausting it from the annular cha to the atmosphere. It is opened by a reversal of this oper The supply and exhaust to and from the operating chamber controlled by a valve of the balanced-piston type. This is actuated through a floating lever, one end of which is att to a lever on a rocker shaft which is connected internal the moving plunger. By means of this arrangement the pl cannot travel faster than the control valve, and if it shoul any reason be desired to stop the stroke of the valve pl

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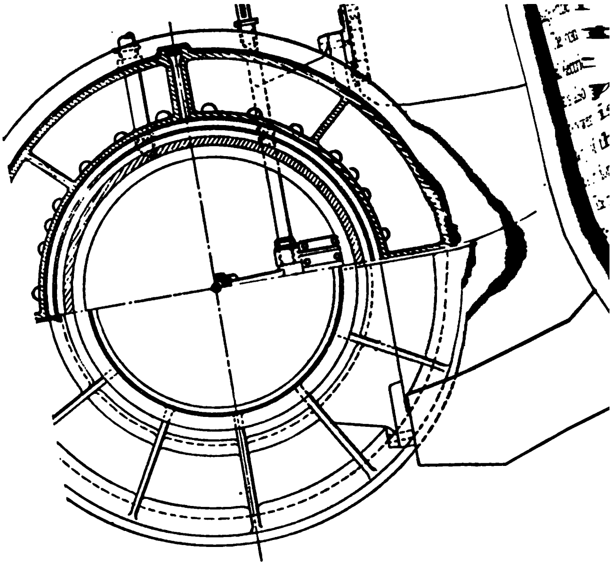

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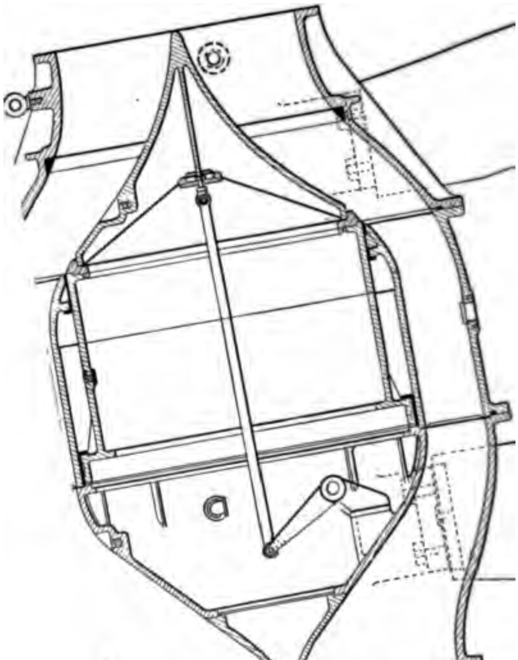

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at any intermediate position it can be readily done and the plunger will be automatically maintained at that position regardless of leakage either around the plunger or through the control valve.

The control valve may be operated either by hand or by a small electric motor. In the latter case a means of hand operation is also provided. The control valve is balanced and very little power is required to operate it. If a motor is used, the capacity of the motor need not exceed ½ hp. under the highest heads or for the largest sizes.

The motor is provided with a limit switch to prevent overtravel, and the connections between the motor and the control valve are so designed that the plunger begins to move very slowly and attains its maximum speed at one-half stroke. It then slows down and the end of the stroke is made at very slow speed. This is desirable in order that the plunger may seat itself slowly. You will observe that it seats at both ends of the stroke.

This valve lends itself very readily to distant control. Some of the valves we are now building will be located several hundred feet from the power house and controlled from the switchboard. In such cases an electric indicating device is provided on the switchboard in conjunction with the control switch, to show not only the open and closed positions of the valve but also intermediate positions during the stroke.

A valve of this type has been in use in the plant of the Ontario Power Co. at Niagara Falls for a year or more, and has given entire satisfaction. Careful tests show that if there is any loss of head through the valve it is too small to be detected.

You will observe that one end of the valve body is smaller in diameter than the other end. The large end is made to conform to the penstock diameter, and a taper section is used to connect the small end of the valve body to the penstock. If this valve is used in connection with a spiral casing wheel in which the velocities are fairly high, it can be very conveniently placed at the entrance to the casing and the small end of the valve connected directly thereto. This, of course, does away with the necessity for a taper piece of pipe, and at the same time dispenses with the penstock reducer which would otherwise be used for accelerating the velocity from that used in the penstock to that used in the wheel casing.

We are now building three 8-ft. horizontal valves of this type for the Salmon River Power Co. to operate under 200 ft. head, and two 9-ft. vertical valves for the Ontario Power Co. to operate under 100 ft. head. All of these valves will be equipped with distant electrical control and indicating devices.

Very truly yours,
THE WELLMAN-SEAVER-MORGAN CO.,
Chester W. Larner,
Hydraulic Engineer.

THE CHAIRMAN: Before opening the discussion of this report, I am going to call for the next paper, which is more or less allied with this part of the Prime Movers report. The paper is entitled "A New Type of Thrust Bearing," and has been prepared by Mr. Albert Kingsbury, of Pittsburgh, who will read the paper.

A NEW TYPE OF THRUST BEARING

While the bearing is designated as a new type, it is new only in so far as old and well-established principles have been adapted to new uses. The bearing is made up of elements individually identical in function with the common cylindrical shaft bearings which depend upon automatic lubrication for their operation.

Fig. 1 shows the elements of one form of the thrust bearing

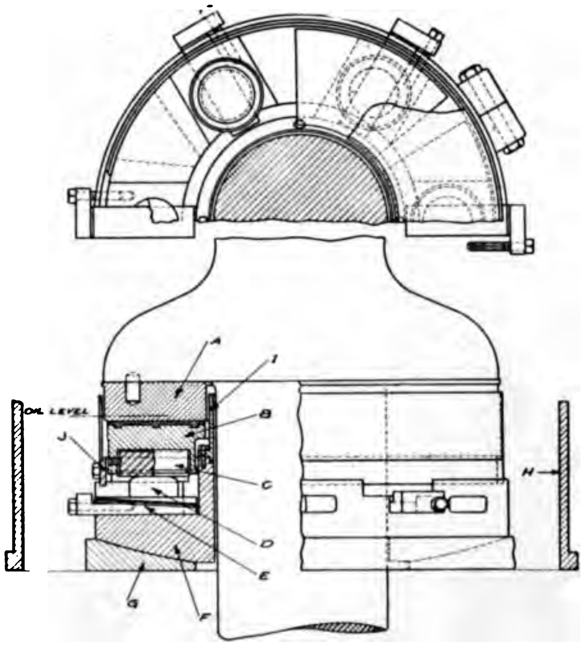

FIG. 1. A NEW TYPE OF THRUST BEARING

applied to a vertical shaft. A is a runner or washer attached to the shaft collar and rotating with it. The runner slides upon the stationary shoes B, these shoes having the form of sectors of a ring. Each shoe is supported against the thrust by hardened pieces C and D, one of which is made crowning on the face in order to permit the shoe to rock slightly and thereby adjust itself to the best bearing conditions at the sliding surface. E is an

adjusting wedge, by means of which the shoes may be individually adjusted for equal division of the load or for endwise adjustment of the shaft position. The base ring F which holds the shoes is either supported on a spherical leveling washer G, or directly on the flat base. The bearing is contained in a housing H, which is kept filled with oil to a level somewhat above the sliding surface of the collar. An oil retaining ring I is attached to the base ring, or else directly to the floor of the housing. The retaining pieces J hold the shoes in place radially, the shoes being held circumferentially by lugs entering radial slots in the

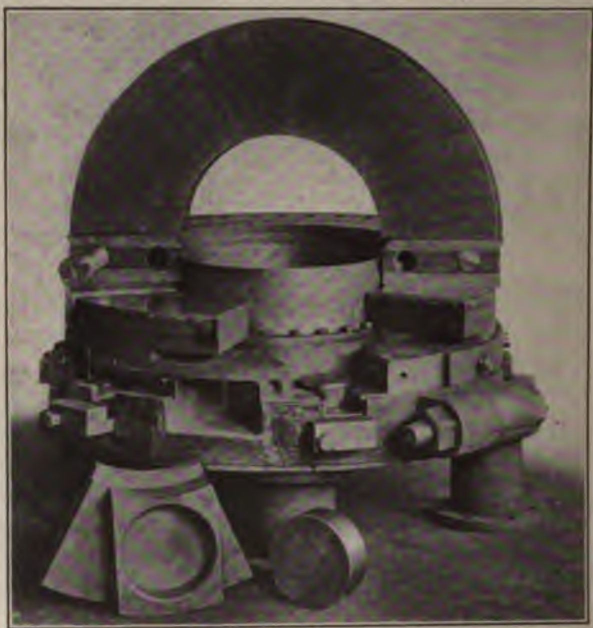

FIG. 2. THRUST BEARING, 48-INCH DIAMETER, MADE IN HALVES WITH WEDGE ADJUSTMENT FOR THE SHOES

base ring. The shoes may be individually removed by withdrawing the wedge and removing the retaining pieces. The oil circulates through the large holes in the base ring and between the shoes. The collar in its motion drags the oil with it across the shoes, forming an oil film between each shoe and the collar, as will be described later.

Fig. 2 is a photograph of the bearing outlined in Fig. 1, ithout the leveling washer. It will be understood that not ll of the details referred to are essential to the device. The ital feature of the construction consists in the separate shoes, ach one supported in such a way as to permit it to rock or ivot slightly upon the support.

The design as outlined above is based upon the principles stablished by Osborne Reynolds in his "Theory of Lubrication."* 'rofessor Reynolds was led to make a theoretical investigation y the striking results obtained by Tower in his experiments for ie Institution of Mechanical Engineers.† Tower, experiment- ig with a well-fitted cylindrical journal flooded with oil, found iat there was practically no wear, that the total friction was early independent of the load, and that the mean co-efficient of iction was very low, in some cases not exceeding 0.001. He irther found that there was oil between the shaft and the brass ider pressure which varied from point to point on the bearing irface, the maximum pressure being roughly twice the mean pres- ire and the integrated pressure being equal to the total load on e bearing. The obvious inference from these experimental results as that the oil formed a film between the shaft and the brass, impletely separating the surfaces, and reducing the friction to at within the oil itself. Reynolds based his theoretical work i elementary physical data, including the shaft diameter, its eed of rotation, the dimensions of the brass, the viscosity of e oil and the load on the journal. He assumed, what indeed id been experimentally proved, that the particles of oil in tual contact with the shaft or the brass do not slip on the etal surface, but remain fixed in contact therewith, while other irts of the oil are subject to more or less motion parallel to e surfaces as influenced by the distance from the surfaces, the scosity of the oil, the pressure and the motion of the surfaces. pon these assumptions he was able to calculate the friction id what the pressure should be at any point in the oil film, and s calculated results agreed fairly well with Tower's experi- ental results. He furthermore derived certain important re- ilts, which did not appear directly from Tower's experiments. mong these, and perhaps the most important of all, is the fact

* Phil. Trans. 1886.

† Proceedings of the Institution of Mechanical Engineers 1883, 1885, 1888, 1891.

that the cylindrical surfaces of the shaft and the brass are not concentric, but that a slight eccentricity always exists, in such manner that the oil film may be roughly stated to have the general form of a very thin wedge. This wedge is thickest toward the side where the oil enters with the shaft in its rotation, and thinnest toward the leaving side. The oil, because of its adhesion to the shaft and because of its viscosity or resistance to flow, is dragged into this wedge-shaped space by the shaft in its rotation, and this action sets up the pressure in the oil, which, in turn, supports the load on the brass. This wedge-shaped film of oil was shown by Reynolds to be the absolutely essential feature of effective automatic lubrication. Without it no great load can be borne on the bearing except with the accompaniment of high friction.

In the ordinary shaft journal the formation of the wedge-shaped film of oil causes a slight lifting of the shaft against the load together with a slight lateral displacement. It is well known that bearings of this type are reliable and satisfactory in their operation. Ordinary collar bearings, however, such as are commonly used on line shafting and the like, are not only deficient in load carrying capacity, but such small loads as they carry are accompanied by relatively high friction. This was well brought out in some of the experiments of Tower previously referred to. The reason for this is evident from the principles established by Reynolds. The surfaces are everywhere parallel, with no possibility of relative adjustment such as to permit the formation of a wedge-shaped film of oil. The new type of bearing may be regarded as a collar bearing in which one of the collars has been cut into several sectors, each of the sectors being so mounted that it can pivot over its support. This freedom of support enables it to adjust itself to the rotating collar so that the desired wedge-shaped film of oil is formed between each sector and the collar.

The theory of lubrication cannot be entered upon here. It may, however, be stated that the approximate theory, which assumes the shoes to be indefinitely wide in the radial direction, indicates that for the greatest load supporting power of an oil film of given minimum thickness and at the same time the lowest friction, the point of support of the shoe should be placed not less than 10 per cent of the width of the shoe away from its

center of figure in the direction of the motion of the shaft collar. Nevertheless it is found by trial that if the point of support is placed exactly under the center of area the bearing has fully as great load-carrying capacity as when provided with the eccentric support. The friction, however, is much greater when the support is central. The reason for the high load-carrying capacity with the central support appears to be that the effect of leakage at the edges of the film is such as to cause the film to take the wedge form to some extent, yet not to form the thickest pos-

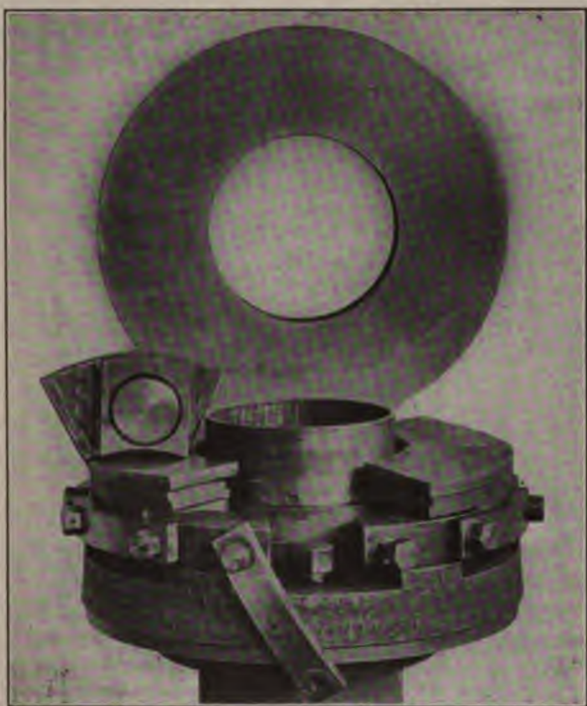

FIG. 3. THRUST BEARING, 21-INCH DIAMETER, WITH SCREW ADJUSTMENT FOR HEIGHT OF SHOES

sible film. The calculated average thickness of the film is very small even under the best conditions, being at most a few thousandths of an inch in very large bearings, and often less than a thousandth of an inch in small bearings. The thickness of the film may be roughly stated to be two to three times as great at

the entering edge as at the leaving edge when the point of support is in the best position.

The capacity of the new thrust bearings depends upon many conditions, chief among which are the speed of rotation, the dimensions of the bearing and the viscosity of the oil, together with the provisions for removing the heat generated by the friction in the oil film. The pressures ordinarily allowed are 300 to 400 lb. per sq. in. in vertical hydro-electric units, and up to 500 lb. in horizontal steam turbines. The capacity of the bearing is relatively much greater than that of the cylindrical shaft bearings, apparently because the automatic adjustment of the shoes is independent of any question of clearance or of curvature of the surface. The thickness of the film increases as the speed increases, being approximately proportional to the square root of the speed as indicated by the theory. Higher speed also enables higher load to be carried with a given thickness of oil film.

General rules that have become well established for shaft bearing practise apply equally well to the new thrust bearing; that is, for low speed and heavy loads a thick oil must be used, while for high speed and light loads, thinner oil is required. It is also found that for high speeds it is preferable to have the shoes faced with babbitt metal, the collar being of cast-iron or mild steel. For very low speeds, coupled with high unit pressures, hardened steel or chilled iron may be used for the collars, and brass or bronze for the shoes.

The friction of the new type of bearing is, as a rule, satisfactorily low. It depends on numerous factors, including the speed, the load, the viscosity of the oil and the temperature attained. It also depends upon the number and the shape of the shoes and the position of the points of support. An approximate rule for bearings having six eccentrically supported shoes with inside diameter one-half the outside diameter, and loaded to 350 lb. per sq. in. of shoe area, using dynamo oil and keeping the temperature at about 40 deg. cent. makes the mean co-efficient of friction $0.00009\sqrt{\text{rev. per min.}}$, and varying inversely as the square root of the unit pressure. For example, if the shaft runs at 100 rev. per min. the mean co-efficient of friction is 0.0009 if the pressure is 350 lb. per sq. in. It will be noted that this is

an extremely low co-efficient, the result being due to the nearly ideal conditions for automatic lubrication.

The starting friction is an entirely different matter. When the shaft is at rest, with the load on the thrust bearing, the continuous oil film is not present, and the co-efficient of friction between the metallic surfaces is very high, apparently averaging about 0.15. At the instant of starting there is some rubbing between the metals. In the bearings with babbitted shoes this rubbing is frequently evidenced by a sound like that of a hot bearing.

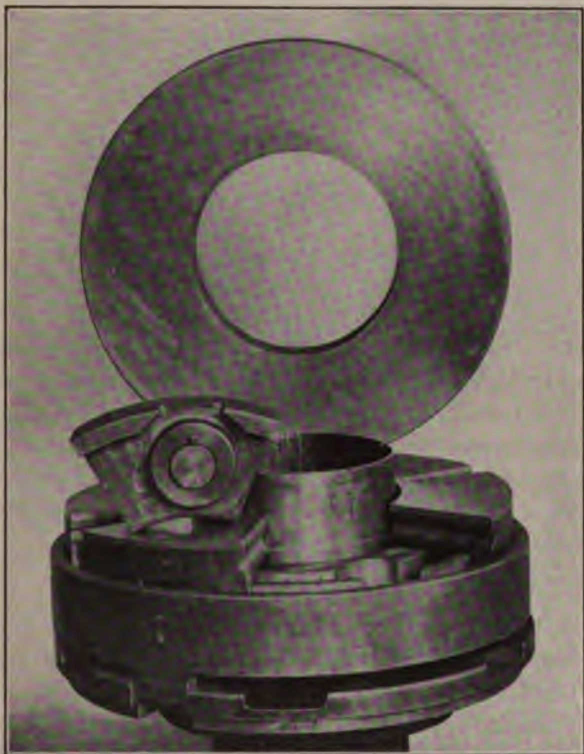

FIG. 4. THRUST BEARING, 18-INCH DIAMETER, WITH LEVELING WASHER AND NON-ADJUSTABLE SHOES

The rubbing lasts only a very brief time, the oil film beginning to form at the instant of starting, and increasing in extent and thickness as the speed increases. If the bearing is provided with

clean oil the only wear that takes place is that due to the rubbing of the metals when starting and stopping. For conditions such as exist in horizontal steam turbines there is very little load on the thrust bearing at starting, and hence no reason to expect much wear. With vertical hydro-electric units and similar machines, in which the entire weight of the rotating part is carried on the thrust bearing at all times, it is found that the wear of the bearing is practically negligible.

Following are some test results, which will serve to show the general range and capacity of the new thrust bearings:

Case I

Thrust bearing 4¾ in. outside diameter, with 10 babbitted centrally supported shoes of approximately 1 sq. in. each, run at 3500 rev. per min., mean speed 3250 ft. per min., with a free supply of turbine oil circulated through the bearing. The maximum available load was 11,700 lb. The bearing carried this load without distress. By successively removing shoes, nearly the same total load was borne on eight, six, four and two shoes, the latter condition giving a mean unit pressure of 5400 lb. per sq. in. The babbitt on the two shoes was finally cut away, leaving about 0.6 sq. in. on each shoe; the bearing was then loaded to 11,700 lb., or 9800 lb. per sq. in. nominal area, and carried this load without overheating or injuring the surfaces. The babbitt, however, spread under the pressure so that its area increased to 0.83 sq. in. per shoe, thus making the actual mean pressure 7050 lb. per sq. in. In all these tests the runs were of short duration.

Case II

Thrust bearing 10 in. outside diameter, tested on a vertical motor-driven pumping unit; 6 babbitted shoes, centrally supported. Load 17,900 lb., pressure 390 lb. per sq. in., speed 300 rev. per min. The housing contained about 10 gal. of oil, with no external circulation. The bearing gave satisfactory operation during several days' test, the maximum temperature rise being 36 deg. cent. above the surrounding air.

Case III

Thrust bearing for vertical hydro-electric generating unit, 6 babbitted shoes with eccentric supports (Figs. 1 and 2), out-

side diameter of shoes 48 in., total load on bearing 410,000 lb., area of shoes 1160 sq. in., unit pressure 350 lb. per sq. in., 94 rev. per min., mean surface speed 900 ft. per min., light mineral oil flowing through bearing at the rate of 15 gal. per min., mean temperature rise of oil in bearing approximately 3 deg. cent., frictional loss in bearing approximately 9 hp., co-efficient of friction approximately 0.0008. A test was made at a speed of 10 rev. per min., the mean surface speed being 95 ft. per min., and it was found that, at this low speed, the oil film was maintained, and that the lubrication was entirely satisfactory. The friction was much less than at full speed—so small that no definite data as to its value could be obtained.

A test was made without the continuous fresh supply of oil. The housing contained 570 gal. of oil, and the heat capacity of this oil and the metal parts enabled the bearing to be run at the normal speed of 94 rev. per min., with a temperature rise of only 3 deg. cent. in one hour.

This bearing was inspected after 3½ months' service. No measurable wear was found, the bright contact spots on the babbitt having increased in area but slightly since being put in service. At the present time this bearing has been in service nearly a year without giving trouble or requiring attention.

DISCUSSION

THE CHAIRMAN: Is there to be discussion on either the water power portion of the Prime Movers Committee report, or on Mr. Kingsbury's paper?

MR. J. C. PARKER, Rochester: The contribution by Prof. Allen to the report is of so great value that discussion should not go by default on it. I think that ordinarily operators have been inclined to attach a great deal of importance to switchboard measurement of electrical output, and but little importance to the measurement of wastage in the boiler room of a steam plant, or in the turbines of a hydraulic plant.

Prof. Allen has laid a great deal of stress in his paper on the importance of hydraulic efficiency tests. It is readily possible for the efficiency in operating conditions of a hydraulic plant to fall off 4, 5, 10 or more per cent. I think few of us realize until we have got to the hydraulic efficiency test, just how rapidly a

hydraulic plant will deteriorate without any signs of distress. A decrease in efficiency of 10 per cent in a hydraulic operating plant means that 10 per cent of the plant investment and of the capitalized operating cost is absolutely useless. It might easily be that such a deterioration would mean $10 to $20 of capital investment per horse power of the plant absolutely put out of effective service. On a single unit running in the neighborhood of 10,000 horse power, that represents quite a tidy sum of money and will justify a great deal of careful testing.

The Rochester company has during the last year made hydraulic tests for efficiency on practically all of its stations. The results of these tests have been astounding to us. As a matter of pride in our own housekeeping I would scarcely care to put into the record of discussion what our findings were. It is sufficient to say that those findings resulted in our determining to retire from use two of our hydraulic stations and to supplant them by one other, completely rebuilt from the ground up. That is an indication of the dollars and cents value of efficiency tests on existing hydraulic plants.

I should certainly urge that no company design a plant without making provision for frequent and simple tests of the water in-put. I do not believe that the weir method or current meter methods are particularly satisfactory. The weir is after all only a secondary standard, and where the quantities measured are very small there is liability to grave error under the formula that you may use as your own particular pet. Moreover, an investigation of the weir formulæ in common practise will indicate that you can use a formula that will vary the results by as much as 5 per cent, simply by selecting one that looks good to you. I believe, therefore, that it is better to adhere to the absolute standard of measurement which you can get through a Pitot tube.

Inasmuch as the losses in any modern generator are very small, so that the losses themselves are pretty nearly within the limits of error in the hydraulic test methods, and as these losses are little liable to change, I believe that, at least for comparative test purposes, the direct generator load is preferable to the brake load recommended by Professor Allen. What we are interested in, after all, is the input-output efficiency of the generator unit—turbine and generator combined. I, therefore, feel that we can get the most satisfactory results by metering the water input.

either through a Venturi contraction in the pipe line, or through a permanently installed Pitot tube, and metering the output by the switchboad meter, or a special meter installed during the test period.

MR. RUSHMORE: In glancing over this report very hastily I see one point brought out regarding water-wheels of which I do not find any explanation. Having myself examined a great many wheels that have been eaten up in this way, I would say that it is quite impossible for this action to have taken place because of eddy currents in the water. A considerable discussion in the past, in which we have always been helped by Dr. Steinmetz, has brought out the theory that a partial vacuum is created which draws the oxygen out of the water. After the oxygen comes out, it is quite active chemically, and in that way it has an action very different from the actual water itself or the oxygen in the air.

THE CHAIRMAN: I am afraid we shall have to limit discussion on this subject. There is another session to follow this one, but before we adjourn this first session of the Hydro-Electric Section, it is in order to select a nominating committee.

Nominations are in order.

A MEMBER: Mr. Holton H. Scott.

A MEMBER: Mr. A. A. Dion.

A MEMBER: Mr. F. B. H. Paine.

THE CHAIRMAN: Mr. Holton H. Scott, of New York City; Mr. A. A. Dion, of Ottawa, Ill., and Mr. F. B. H. Paine, of Buffalo, N. Y., have been named as members of the Nominating Committee. (It was moved, seconded and carried that the nominations be closed and the Secretary instructed to cast one ballot for these gentlemen to compose the Nominating Committee.)

THE CHAIRMAN: We will close the first session of the Hydro-Electric Section.

(Adjourned.)

SECOND HYDRO-ELECTRIC AND TRANSMISSION SESSION

THURSDAY AFTERNOON, JUNE 5

THE CHAIRMAN, MR. W. N. RYERSON: We will first listen to a paper entitled Poles and Pole Preservation, by Mr. R. A. Griffin of New York City.

POLES AND POLE PRESERVATION

Mr. Chairman and Gentlemen of the National Electric Light Association:

I greatly appreciate the honor of the invitation extended to me by your Secretary, Mr. Martin, to appear before this large body of thoughtful and exceptionally able engineers and electrical business men, to address you on the subject of poles and pole preservation. It is a subject in which I have been particularly interested for some 20 years; first through my connection with the American Telephone and Telegraph Company, and since 1904, as manager of the pole department of the Western Electric Company, and I can appreciate that it is a subject in which your companies now take an active interest as a result of the marvelous growth of your industry in recent years, and your consequent heavy investment in pole lines.

To those interested, few subjects in recent years have received closer or more careful and earnest study and research than that pertaining to the proper building of pole lines and to the preservation of those lines after they are built. Of primary importance is the selection of the best woods to use for poles and then the determination of the size of poles to insure the necessary strength for a required capacity. Finally, and quite as essential to the interests of the operating companies, is the question of the preservation from decay of the poles in their lines, in order to insure the maximum life at a minimum investment. This latter question is one that may also properly be classified as a feature of the great question of the conservation of the country's timber supply in which our government is so vitally and properly interested at the present time.

The demand for wooden poles during the past few years by the telephone and telegraph companies, the electric light and power companies and by the railroads, has been enormous. The latest census report shows that in 1910 approximately 3,870,000 poles were purchased—this means a similar number of trees, for ordinarily but one pole is made from a tree. The consumption in 1911 and 1912 was unquestionably greater, though no census figures have been furnished. My company alone, which dis-

tributes throughout the entire United States, in 1912, sold, handled and shipped, considerably over a million poles, and our shipments this year are being made at the rate of over one and one quarter of a million poles. I cite these figures in order that you may the better appreciate the drain on our forests and the consequent necessity for immediate careful consideration of the best methods for preserving your pole lines. Four million poles a year, at say an average of $3.00 each, is an annual investment of $12,000,000.

At the end of the year 1912, the Bell Telephone System owned 315,000 miles of pole line, or at 40 poles to the mile, 12,600,000 poles. Add to this approximately 225,000 miles of pole line in the plant of the Western Union Telegraph Co. and we find over 20,500,000 poles standing to-day in the lines of these two great systems; sufficient to build a continuous pole line 21½ times around the world. To reproduce this plant would, on a basis of an average of 40 poles to the acre, which is a fair approximate production, require a forest of 800 square miles. In addition, the electric light and power companies are purchasing wooden poles now at the rate of approximately 700,000 poles a year. Within a very short time we shall unquestionably see an annual demand in this country for maintenance and replacements alone of 2,500,000 poles. We can figure the average life of an untreated cedar or chestnut pole, set in the ground, as 12 to 15 years. It requires an average of about 60 years for a tree to attain a growth suitable for poles; it is seen, therefore, that the production takes place at about one-fifth the rate of consumption. The actual amount of available timber is constantly decreasing, but we see no corresponding decrease in the demand, but rather an increase, and the actual supply to-day is being greatly taxed to meet the great demands upon it. It would therefore seem to be essential:

(1) That even better attention be given to the preservation of our forests.

(2) That better care be given the economical utilization of our present timber supply.

(3) That the large users of poles should at once make preparation for the preservative treatment of their permanent lines by artificial methods.

The timber resources of this country have been so vast that we have without thought, wasted them, until now we are facing the vital necessity of greater care and thought for the future.

The problem of increasing the life and service of wood is one which is of the greatest general interest to every consumer of timber to-day. It is the problem in its application to poles that I wish particularly to treat.

The trees of this country are divided into three classes:

(1) The needle-leaved or conifers, such as cedars, pines, etc.

(2) The broad-leaved trees, such as maple, hickory, elm, oak, chestnut, etc., and

(3) The palms.

The broad-leaved trees are deciduous, i. e., they shed their leaves annually, while the conifers are known as evergreens. In the lumber trade the broad-leaved trees are generally known as "hardwood," while the conifers, or evergreens, are known as "softwoods."

Wood is composed of a multitude of cells or tubes, closed at the ends, and which are firmly united and lie up together to form the wood structure. The wood cells are not uniform, but differ in their diameter and length and the thickness of their walls. A new layer of wood is formed each year on a living tree, covering the entire trunk and all the branches. Each layer forms a complete casing around its inner neighbor so that the whole tree is built up of a series of cylinders or cones. It is the outermost rings of the wood in a tree that carry the sap and constitute the living elements. It is in them that the circulation of water takes place. As the center of the trunk is approached the wood cells gradually lose their contents and become filled with air; it is this part of the tree that is known as the heart. The heartwood in most trees is easily distinguished from the sapwood by its darker color. The heartwood has no part in the life of the tree and no sap is carried through the heart. The depth to which the living elements extend depends on the nature of the tree. In some trees it extends through some 30 rings, or 30 years of growth, while on others, such as red cedar, through but 15 rings. The heartwood contains less of water and starches than the sapwood, and the walls of these mature cells are filled with coloring matter, such as resins and gums, making the heartwood heavier, harder

and more durable than the sapwood; consequently the greater the proportion of heartwood, the more durable is the wood.

Only those woods which are the most durable after the trees are cut are used for poles—durability in wood meaning the length of time which it remains serviceable as a consequence of the sound condition of its fiber and its freedom from decay. Timber is classified as long-lived and short-lived, in proportion to its ability to resist decay. Hardness and density apparently have no bearing one way or the other on its durability; white oak, for example, though a very hard and strong wood, decays very rapidly in the ground, and consequently is not suitable for poles, whereas the light, porous and in some respects, defective swamp cedar, resists decay and is a comparatively long-lived timber. Chestnut wood is stronger and heavier than cedar and makes an excellent pole, though the process of decay is somewhat more rapid than in the cedars. Cedar (both Northern and Western) is used more extensively for poles than any other wood, over 60 per cent of the consumption at present being of this wood. At present, by far the largest part of the cedar poles is produced in Minnesota, Wisconsin and Michigan, but the Northwest (Washington and Idaho, as well as British Columbia) is being called upon for a constantly increasing supply. A highly organized system of producing and distributing cedar poles by modern lumbering methods has been developed, in which my company has become very much interested in the past ten years.

Next in importance to cedar for use as poles is chestnut, grown in the Eastern States. This wood supplies approximately 20 per cent of the poles used. The chestnut is rapidly disappearing in consequence of a very serious blight which has affected wide areas. Even though dead at the time of cutting, if the wood is sound the tree is entirely suitable for use as poles. Government investigations show that this blight, which is a bark disease, kills the tree by girding the trunk and that unsound or rotten wood is not a consequence of the disease. Strength tests made upon chestnut killed by the bark disease, show that sound wood from dead trees is as strong as the green wood of the same species, seasoned to the same dryness.

By the decay of timber we mean the change from the sound or perfect condition to an inferior state. It is now known that decay is caused by the activity of lower forms of animal and plant

life. The living organisms which cause the decay of wood may be insects, bacteria or fungi. Insects bore into the sound wood and sometimes so riddle it that it falls to pieces. These insects, such as beetles and white ants, are particularly active in the hot climates, and the teredo abound in Southern waters; but decay in the sense in which it is usually understood is caused by bacteria or fungi. These fungi are so minute that they can be seen only by the aid of a powerful microscope, but the fruiting bodies of these fungi, commonly called toadstools, are familiar objects to you all. They are a lower class of plant life which obtain their food by breaking up the chemical compounds of which wood is composed. They bring about changes in the wood by excreting chemical substances known as ferments, which exert a soluble action on the wood cells. The conditions necessary for, and favoring the development of the wood-destroying fungi, are, organic food materials, air, water and heat.

If one or more of these essential requirements is lacking the fungi cannot thrive and the decay of the timber will be prevented. Wood continually submerged in water will not rot, because of insufficient supply of air, nor will decay occur where the wood is not subjected to moisture. No fungus growth will take place under water or in the ground at a depth of two feet or more.

The decay of a pole takes place principally at the ground line. The upper part of the pole, permanently in the air, and exposed to little or no water, except rain from which it rapidly dries, is rarely found decayed. The deeply buried part of the butt, though permanently damp, does not decay, because it is devoid of air. The maximum decay in a pole therefore occurs at the point where it is subject to the combination of air, moisture and heat, the ground holding the moisture keeping the timber constantly in an environment of air. Even under the best conditions we can get but a short life out of our poles, notwithstanding that they are selected from the long-lived timbers. It is for this reason that recourse has been taken, in many instances, to chemical means to make these poles immune to decay.

Chemical preservation involves the injection into the wood of some substance which will poison the fungi which cause the decay. There are a large number of so-called wood preservatives on the market of which but a few have been found worthy of the

name, or of much consideration. The ideal preservative should conform to the following conditions:

(1) It should be highly preservative; that is, poisonous to bacteria and other destroying agencies.
(2) It should be of a character to penetrate the wood easily and deeply.
(3) It should remain in the wood and not be soluble or volatile.
(4) It should be cheap.

Experience here and abroad has shown that the best timber preservative is coal tar creosote, though other preservatives, such as chloride of zinc, copper sulphate and bichloride of mercury, have been used with varying degrees of success, but the coal tar creosotes combine the essentials above enumerated, to a greater degree than any other preservative yet discovered or introduced.

Many methods for the preservation of timber have been tried, but with no very gratifying results. I will refer to some of them briefly.

CHARRING

This method has been practised from the earliest times. It is of some value, but has its limitations and must be considered at best as only of temporary benefit. Its disadvantage consists in the fact that it is liable to make large checks through which the germs of decay may pass into the body of the wood. Charring is really a detriment unless the wood is absolutely dry; if green or wet wood is charred, a more or less impervious layer is formed on the outside of the wood which prevents evaporation from the interior of the poles and consequently tends to hasten rather than retard decay.

CONCRETE OR LOOSE STONE SETTING

The practise of setting poles in concrete or broken stone has often been followed. The broken stone has given fair results as it allows ventilation and prevents the collection of water. If poles are set in concrete, sufficient air is sure to get in between the pole and the jacket to permit the development of the decay producing fungi.

TAR OR ASPHALT COATING

These substances have no penetrative or antiseptic properties and therefore merely act as a protective jacket. Sufficient air and moisture, however, will work in between the surface of the pole and its covering to permit decay.

PAINTING

Painting hinders the entrance of fungus germs and in consequence tends to act as a preservative, but again, if the wood is painted while green, the effect is only to hasten decay as the excess moisture is held in the wood.

CREOSOTING

Unquestionably the most perfect method of timber preservation at the present time, is the injection of coal tar creosote or dead oil of coal tar into the timber. In commercial practise this is done in three ways:

(1) By the closed tank pressure method

(2) By the open tank method, and

(3) By application with a brush.

I shall attempt to treat these three methods briefly and cite you some of the results which have thus far been obtained in this country. This process of treatment of poles is the only one known at present, which will not only prevent the decay of timber, but which will resist the attack of timber-destroying insects. The work, however, must be honestly and efficiently done; this is of primary importance. Unfortunately much fraud has been practised at various treating plants in this country by the substitution of inferior or adulterated oil, or by injecting into the timber less than the quantity of oil specified.

Dead oil of coal tar, or coal tar creosote, is one of the by-products of the manufacture of coal gas. It is not known absolutely to just what components of the oil the preservative process is due, but the efficiency of dead oil of coal tar and carbolineum (which is practically dead oil of coal tar with many of its lighter distilling constituents removed) has been amply proven, not only in this country, but abroad, and they are now generally recognized as the most effective timber preservatives and best adapted to the treatment of poles. We know that poles treated by this process in England 50 years ago are still in serv-

ice and in sound condition, and complete government records in Germany for the past 50 years demonstrate the superiority of this preservative over all others. American practise and opinion coincide with these results, although our experience has not extended over so many years.

In 1897, while in the service of the American Telephone and Telegraph Co., I arranged for the purchase of some 10,000 creosoted yellow pine poles for a line which was built in that year from Washington, District of Columbia, to Norfolk, Va. These poles were treated their entire length by the closed cylinder pressure process at the works of the Norfolk Creosoting Co., under a specification requiring the injection of 12 lbs. of dead oil of coal tar to the cubic foot. A recent inspection of this line showed it to be in practically a perfect state of preservation. It is safe to say that these same poles, untreated, would have served their usefulness in about four years, as yellow pine rots very rapidly in the ground.

CLOSED CYLINDER PRESSURE TREATMENT

I shall not attempt to describe in detail the method of treatment by the closed cylinder pressure process, as this method, as well as the specification for dead oil of coal tar, was thoroughly covered in the report of your Committee on "Preservative Treatment on Poles and Cross-arms," submitted and approved at your meeting in New York in 1911, and to which I refer you; but the experiments and investigations which have been conducted by the American Telephone and Telegraph Co. during the past ten years or more have indicated that yellow pine can be economically utilized for poles when thus treated, in a large section of this country, particularly in the South. However, on account of the expense of this complete treatment in other sections of the country, many experiments in the partial treatment of poles by the open tank and brush method have been conducted, and I am glad to say that the results thus far obtained have been most gratifying, and even better than at first anticipated.

It is not practical, even with the best methods of treatment to impregnate the wood throughout, nor is such a penetration necessary. The value of the treatment consists in forming an outer protective envelope around the untreated heart; the thickness necessary for this envelope depending on the use to which

the timber is to be put, as well as the character of the wood and the character of the soil in which it is placed. In general, the antiseptic preservative should penetrate deep enough to prevent exposure of the untreated interior by abrasions, checking, etc.

In spite of the excellent results that have been obtained both here and abroad by the full cylinder treatment, such as was used on the Washington-Norfolk line referred to before, the proportion of poles thus treated, as compared with the total number of poles in use, has been relatively small. This method has been resorted to principally in the South, where, on account of the climate and soil conditions, exceptionally rapid decay makes a preservative treatment almost essential. The chief hindrances to a more general adoption of this method for treatment of poles have been the high cost of the treatment and the expense of the transportation of the poles to a treating plant. Recent investigations have therefore been conducted mostly with cheaper and simpler methods, and with treatments which could be applied locally by the consumer, or at the large cedar concentrating pole yards. It should be remembered that approximately 60 per cent of the poles in use are cedar, and about 20 per cent chestnut, and these woods lend themselves readily to the method of partial treatment, which I shall describe.

BRUSH TREATMENT

The brush treatment consists in painting the pole with a preservative, preferably creosote oil. As it is conceded that the portion of the pole most subject to decay is just below and just above the ground line, that is the part selected for treatment, for as that part fails when the balance of the pole is still in a good state of preservation, consequently the usefulness of the pole depends upon the length of time that it can be kept in a state of preservation. The pole should, therefore, be painted about 2 ft. below and 2 ft. above the ground line, or over that section between 4 and 8 ft. from the butt. I would particularly emphasize the fact that only seasoned poles should be treated and that care should be taken to see that the wood is thoroughly dry before the treatment is applied.

It is decidedly preferable that the preservative should be heated to a temperature of 150 to 175 deg. fahr., and distinctly better results will be obtained from two coats rather than one.

Particular attention should be paid to the filling of all checks and knot holes, and to working the preservatives well into the wood. An average 30-ft. pole will absorb, by this treatment, about 4 lb. of oil, or one half-gallon, and if treated under proper conditions a penetration ranging from one-sixteenth to one-eighth of an inch can be secured. The method of brush treating has an advantage that it can be applied with ease in any locality, or along the route of a line in process of construction. It is also a very economical method. In the year 1911 the American Telephone and Telegraph Co. treated 12,000 poles with creosote oil by this method in Nebraska, at a cost of approximately 25 cents per pole; this cost included the cost of the oil and labor. Previous reports of experiments in brush treating estimated an increased life of from two to three years as a result of this treatment, but access to as yet unpublished data, which it has been my privilege to review, indicates that in actual service these estimates will be substantially exceeded, if not doubled. The depth of penetration is comparatively slight, but experience has shown that the protection afforded by the brush treatment is usually destroyed through mechanical impairment, rather than through loss of the preservative by volatilization or leaching, provided always that the material used for treatment is one of the oils known to possess good antiseptic properties.

OPEN TANK TREATMENT

Treatment by this method consists in placing the butt end of the pole in a tank into which an antiseptic preservative, preferably dead oil of coal tar or carbolineum, is poured until the poles are covered for a distance of about 8 ft., or from the butt end to a point equivalent to 2 ft. above the ground line. The oil should then be heated to a temperature above the boiling point of water. The best practise would seem to indicate that this temperature should be maintained until the air in the wood has been expanded and the water in the outer layers vaporized and both as far as possible driven out. In other words, the high temperature should be maintained until bubbles cease to appear on the surface of the oil. The oil should then be permitted to cool, or else the poles be transferred to another tank containing cold oil; a partial vacuum is thus produced by the contraction of the air and the condensation

of the moisture remaining in the wood, the preservative, as a result, being forced under atmospheric pressure into the wood. A treatment by the method described consumes about 24 hours, during which the pole is subjected to the hot oil from 8 to 9 hours. In 1905, the American Telephone and Telegraph Co. treated by this method and by the brush method 600 chestnut poles, which were set that same year in their toll lines between Warren, Pa., and Buffalo, N. Y. The balance of the poles in this line were untreated, part green and part seasoned. The treatment was made in conjunction with representatives of the Government Forestry Department, and various preservatives were used. An inspection of this line made three years ago, five years subsequent to its erection, again in conjunction with the Forestry Department representatives, developed the fact that 100 per cent of the green, untreated poles showed an average loss of circumference at the ground line from decay of 1.16 inches; 99 per cent of the seasoned, untreated poles showing an average loss of 1 inch. Of the brush-treated poles, decidedly the best results were obtained from those treated with coal tar creosote and carbolineum. Decay had commenced sooner and developed much more rapidly in the poles brush-treated with other preservatives. Only 14 per cent of the poles brush-treated with the coal tar creosote oils showed any sign of decay and the average loss in circumference of those in which decay had started was from 0.02 to 0.04 of an inch. You will thus see that though the untreated poles had decayed to the extent of from 1 inch to 1.16 inches, the poles which received a two-coat brush treatment of coal tar creosote had been held in a perfect state of preservation for nearly five years and had only just begun to show signs of decay at the time the inspection was made. The inspection further disclosed the fact that every pole which had received the open-tank treatment which I have described was in a perfect state of preservation. This would seem to be an ample demonstration of the efficiency of the open tank treatment. The greater depth of penetration obtained in the open-tank treatment (approximately two to four times the depth obtained in the best and most careful brush treatment) justifies the expectation that mechanical impairment and damage from checks will not play so important a part in connection with the initiation of decay as in the case of brush-treated poles. It should be thoroughly understood, however, that the results

from an open-tank treatment, such as I have described and from which a thorough impregnation is secured, will unquestionably be much superior to the results which may be expected from a short-period dipping treatment, which has been, and is still, frequently advertised as an "open-tank treatment." If not properly performed, the open-tank treatment will not give a penetration appreciably different from that obtained in a two-coat brush treatment and it may safely be considered that a short-period dipping treatment can be ranked only as about equivalent to brush treatments, rather than as in any way comparable with what I should call the *true* open-tank treatment and which was originally developed in the co-operative work undertaken by the Engineering Department of the American Telephone and Telegraph Co., and the Forest Service of the United States Government.

Tests have shown that an average 30-ft. Northern cedar pole will absorb when treated by this method, about 48 lb. of creosote oil, or about 6 gallons. The Western or Idaho cedar poles will absorb on the average about a gallon less and chestnut about half as much as the Northern cedar. On this basis the Northern cedar is the most expensive to treat of the more largely used woods, but as it absorbs more oil with a consequent greater penetration, the results should justify the somewhat higher cost. For the sake of comparison we may say that a 30-ft. chestnut pole can be treated for 75 cents, whereas, on account of the greater quantity of oil consumed, it will cost approximately $1.00 to treat a cedar pole of the same size.

Some experiments have been made in the treatment of Western yellow pine in California. This wood will absorb 20 per cent more oil than Northern cedar.

DISCUSSION

MR. JAMES F. COLE, Altoona, Pa.: Mr. Chairman, I would like to ask if the prices mentioned in the next to the last paragraph relate to the treating of the entire pole or just to the butt?

MR. GRIFFIN: The prices noted in the paragraph to which you refer represent the average cost of treatment of about eight feet of the butt end by the open tank method.

MR. C. S. VAN DYKE, Schenectady: Will the gentleman give his opinion as to what oils or carbolineum we should use? You

can get dead oil of coal tar, creosote, for 20 cents a gallon, or thereabout. You go to the imported carbolineum oils, and they run from 50 to 75 cents a gallon. Is there a real difference in the value of them in the results that you will get from them to correspond with the difference in price? One is the domestic article, I understand, and the other is imported.

MR. GRIFFIN: Yes, the carbolineums are imported oils. Unquestionably good results have been obtained from their use—a carbolineum oil which will pass the specifications embodied in your Preservative Committee's report of two years ago will give good results. What I wish to make clear, however, is the fact that creosote oil is preferable to all other preservatives and it is safe to use any creosote oil which will pass the standard specifications.

MR. VAN DYKE: One more question on the brush treatment of poles. Is it necessary to treat the whole butt of the pole, or is it worth while?

MR. GRIFFIN: I spoke of that in my paper. In the brush treatment of a pole treat only about two feet above and two feet below the ground line. As a matter of fact, I doubt if treatment is needed for the full two feet above the ground line, but it is a safe practice. An average 30 foot pole will absorb when painted two coats with a brush, about one-half gallon of oil or four pounds. It would not be necessary to treat as much of the butt as we do but for the fact that in the open tank treatment no method has been devised for successfully treating merely that portion just above and just below the ground line.

MR. BALLSLEY, Chicago: I would like to ask if it is advisable to go to the expense of shaving the butt of the pole?

MR. GRIFFIN: No, I should not say so. It is, however, necessary in any treatment of timber to see that the inner bark is taken off, because the oil will not penetrate bark; but actual shaving is not necessary.

MR. COLE: I would like to go on record as endorsing what Mr. Griffin has said in regard to the apparent value of the cheap creosote oil, or what is known as "dead oil," a by-product of the manufacture of coal gas, as a preservative for poles and cross arms. We have been using it about two years for this purpose; up to that time we had been using the more expensive material known as "avenarius carbolineum."

It was with some hesitation that we changed to the cheaper material, but the difference in cost was so great, that we finally decided to do so. This we did without any chemical analysis and are pleased to learn that our snap judgment has been corroborated by an expert analysis and a test of time.

MR. W. K. VANDERPOEL, Newark, N. J.: I want to say as ex-chairman of your Preservation Committee, that Mr. Griffin's paper, although very brief, contains some very valuable recommendations, and it has, I believe, the endorsement of all the ex-members of your ex-committee.

THE CHAIRMAN: If there be no further discussion, we will pass on to the next number, Survey of Conditions of Protection, by Mr. E. E. F. Creighton, of Schenectady.

SURVEY OF CONDITIONS OF PROTECTION

In the following, a brief review will be given of a few of the much used protective devices, with brief statements regarding their operation, their application, and the latest developments. One naturally begins, in a review of this kind, with the older types of arresters. The multi-gap arrester has not been entirely superseded by the aluminum arrester. The multi-gap arrester still holds a predominant position in distribution work at or about 2300 volts. This is due to two conditions: first, the lesser cost of the multi-gap arrester; and second, the possibility of making an arrester of this type which is not sufficiently sensitive to operate when arcing grounds take place, but is still sensitive enough to protect transformers. This favorable condition comes from the fact that the factor of safety in a lighting transformer is over five, whereas on the high potential transformers it is usually less than three.

No material technical improvements have been made in the multi-gap arrester during the past few years. A high resistance path shunting out most of the gaps, acting in the capacity of a teazer circuit to bring the spark part way down the line of gaps, is still used. The improvement in protection of lighting transformers comes from recognition of the necessity of placing a lightning arrester at each transformer in order to get a high degree of protection. A perfect arrester situated a few poles distant from a transformer will give comparatively little protection to the transformer because the potentials from lightning are usually very concentrated and localized. With the requirements of a lightning arrester at each transformer, there naturally arises the necessity of an installation of arresters at less cost than is given by the standard multi-gap arrester in a wooden box. At the same time it is desirable to make the arrester equally efficient in protection, and stable against self-destruction. Naturally, all these factors cannot be obtained in their fullest. This endeavor to lessen the cost has led to the development of a self-housed, self-contained arrester known in the trade as a compression chamber lightning arrester. In this arrester the high resistance shunt has been discarded and more gaps have been put in series than were formerly used with the standard multi-gap arresters. This greater

number of gaps gives better arc extinguishing qualities to the arrester. If it were not for the addition of an antennæ around the greater number of gaps, the spark potential would be increased. The employment of the antennæ, however, permits the use of double the number of gaps without any increase in the spark potential. This statement applies to a frequency of 60 cycles. The arrester is actually more sensitive to discharges at high frequency than at 60 cycles.

ALUMINUM LIGHTNING ARRESTERS.

All the technical conditions of design of aluminum arresters have warranted the use of charging resistances and spring clips for the horn gaps on all arresters, just as they have been used on arresters designed for cable circuits. Keeping down costs has lead to a compromise which eliminated the use of charging resistances in most of the installations of aluminum lightning arresters during the past few years. A careful study of the conditions has revealed the fact that the charging resistance is a good investment. Aluminum arresters which have had their films dissolved due to one of several conditions, have failed, not during lightning storms, but during the re-formation of the films. The qualities which make the aluminum arrester a good discharger for lightning, make it also take a heavy current if the films are not in good condition. Although the number of troubles with aluminum lightning arresters is proportionately small, practically all these troubles have taken place during the charging. Since the aluminum cell is a condenser, it is possible to place in series with it a resistance of considerable value, and still not prevent the arrester from taking its full charging potential. This solves the problem of limiting the charging current to a reasonably small value, even although the films are badly dissolved; and of safeguarding the arrester against the destructive effects of heavy dynamic current. Even for an expert there is no outward appearance of the arrester by which he can tell the condition of the films before the circuit is closed. If charging resistances are used the operator can feel perfect security in closing the circuit, in that the resistances will carry the whole current of the arrester circuit for a brief time without damage to themselves. Furthermore, in terms of a popular expression, the arrester is thus made more nearly "fool-proof."

The Spring Clips at the Horn Gaps

Where the films are out of condition, and the arrester takes initially a heavy current rush, the arc at the horns becomes undesirable. Any kind of an arc in a current tends to set up oscillations. For this reason, spring clips are used at the horn gaps, which cut out the arc during charging of the aluminum arresters. With metallic contract across the horns, the wave shape of the current in the arrester circuit is similar to the wave shape of current in any short length of idle transmission circuit. An illustration of this current is given in Fig. 1, page 160. By the use of these clips, and a suitable charging resistance, disturbances in parallel telephone wires can be reduced to a very small fraction of the disturbances that are set up without their use.

Wear on the Plate and Electrolyte

Due to the natural operation of the lightning arrester there is no appreciable wear of the aluminum plates or electrolyte even after several years of operation. Up to January, 1912, an electrolyte was used in which a fungus grew. As a result of this fungus growth, vinegar was formed in the electrolyte which decreased its value in that it hastened the dissolution of the film on the aluminum plate. Since January, 1912, electrolyte has been in use which is fungus proof. This electrolyte has been under observation for three years, and from all indications is serviceable for a great many years more. With this means of preventing the only appreciable deterioration in the aluminum arrester, it seems desirable not to dismantle arresters at intervals, as has formerly been recommended. In dismantling an arrester there is the possibility of wetting the supporting sticks, and thus introducing a spot of weak insulation in the stack of cones. A sufficiently satisfactory and more economical means of investigating the condition of an arrester is found in the use of an ammeter to measure the charging current. So long as this charging current does not exceed one half-ampere at 60 cycles, and one-quarter ampere at 25 cycles, one may rest assured that the aluminum films are in good condition. A convenient method of applying this ammeter to the arrester tanks has been devised. This consists of using an ammeter mounted on a wooden stick, the end of which carries two clips that slide into a jack.

Fig. 1. The lower, or smoother record is the electromotive force; the upper record is the current. The current has an effective value of about 0.4 ampere, at 60 cycles. Since there are contact clips used at the horns, the wave of current has no breaks in it as would occur if the charging were done through a small gap. This wave of current is a typical one for the aluminum arrester.

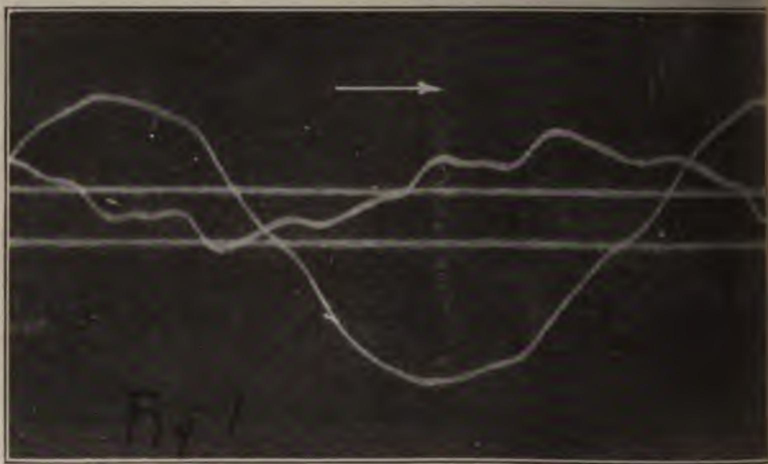

FIG. 1. CHARGING CURRENT AND ELECTROMOTIVE FORCE OF AN ALUMINUM ARRESTER

Fig. 2. The lower record is the potential across the arrester; the upper record is the current through the arrester. It will be noticed that when the gap is first closed the maximum current value is about 11 amperes during the first half-cycle; during the second half-cycle the current drops to about 7 amperes, and each subsequent half-cycle has a value of current too low to be accurately measured, although it is indicated by the irregularities in the zero line. The final value of current is 0.4 amp., the usual charging current.

Fig. 3. The upper record shows both the applied electromotive force, and the current in a number of cells in series. The electromotive force as shown by the first half-cycle is 3200 volts maximum. The circuit is closed during the second half-cycle electromotive force, and the deflection of current goes off the limits of the film. During the third half-cycle, however, the

current maximum is seen to be 55 amperes and each subsequent maximum of current decreases showing a gradual formation of the film. This oscillogram shows a film condition which is undesirable in an aluminum arrester. The lower record is the electro-

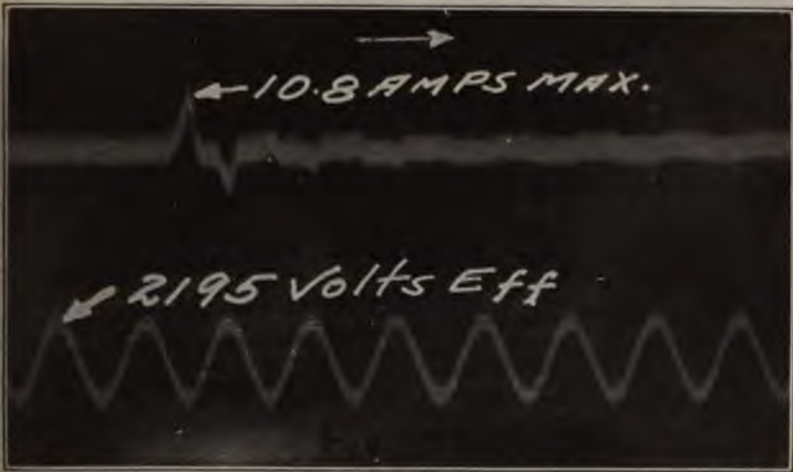

FIG. 2. INITIAL CURRENT RUSH IN AN ALUMINUM ARRESTER WHICH IS IN GOOD CONDITION

FIG. 3. CURRENT ELECTROMOTIVE FORCE OF THE FORMATION OF A FILM IN AN ALUMINUM ARRESTER

motive force across a single cell. This applied electromotive force is about the ordinary value used in the design of the lightning arrester. Attention is specially directed to the form of decreases

in the current, as it is typical of the formation of an aluminum film.

Fig. 4. This 33,000-volt arrester had been allowed to stand disconnected from the circuit in a warm room for six weeks without charging. The charging resistance limits the maximum current to about 10 amperes effective; otherwise, the arrester would have been damaged in charging. The maximum value of current gradually decreases from 15 amperes to 5 amperes in 21 cycles as the film is being formed. This shifts the potential automatically from the charging resistance to the aluminum cells. The growth of the potential across the cells is shown in the upper record where the potential gradually rises from 5800 volts to

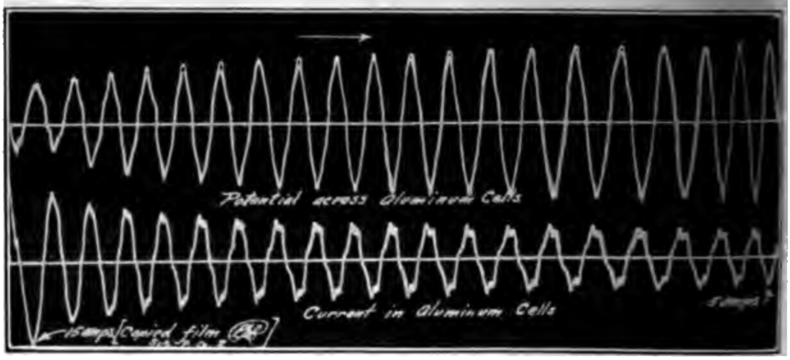

FIG. 4. POTENTIAL ACROSS AN ALUMINUM ARRESTER AND CURRENT IN THE ALUMINUM ARRESTER WHILE BEING RE-FORMED BY THE MOST APPROVED METHOD OF USING CHARGING RESISTANCES IN SERIES

17,500 volts, which is nearly the full Y potential. This arrester was subsequently charged for 15 seconds and was then found to be in good condition.

Fig. 5. The lower record shows the applied potential of 558 volts maximum: the middle record shows a current of about 426 amperes maximum: the upper record shows the potential across a fuse which finally blows. The potential across the open fuse then rises to 690 volts maximum. It required 23 cycles at 426 amperes to cause an arc to form in the electrolyte between the aluminum surfaces. When the arc formed, the action of the film was shunted and the current therefore rose to 1000 amperes.

This heavy current caused the fuse to open. The total energy passed through the arrester was 60,000 volt-ampere seconds, which is ample for all practical purposes in protecting against induced lightning.

Earth Connections

All experience continues to confirm the use of earth pipes consisting of ordinary pipes driven into the ground as far as convenient, and the earth around the pipe thoroughly salted down. In driving a pipe eight feet deep, it is usually more convenient to drive a short piece of a larger size down four feet and with-

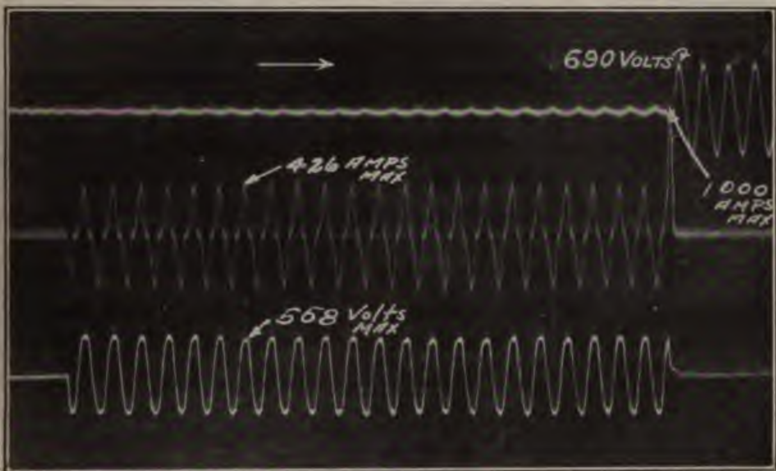

FIG. 5. AN ALUMINUM ARRESTER SUBJECTED TO ABNORMAL DYNAMIC POTENTIALS IN ORDER TO DETERMINE ITS ENDURANCE TO HEAVY DISCHARGES

draw it, and then place the longer piece in the hole, which brings its top within the striking height of a sledge. The question often arises, why put salt around the pipes? The fact of the matter is that practically the whole of the resistance of the earth connection lies in the immediate neighborhood of the earth pipe. The resistance decreases with the amount of moisture around the pipe, and with the conductivity of that moisture. The endurance to withstand continuous current through the earth connection also depends upon the amount of moisture around the pipe. Furthermore, in cases where the pipes have been tried out, it is desirable

to have some material in the neighborhood of the pipe which will naturally attract moisture from the surrounding region. This feature of absorbing and holding moisture, technically known as "deliquescence," is a property of many of the salts. Ordinary table salt, sodium chloride, has this property to a considerable degree, and is a good conductor of electricity. Calcium chloride is one of the most used materials for absorbing moisture, especially from gases. It has a much higher attraction for moisture than ordinary table salt, although its cost is somewhat higher. There are no fancy, expensive kinds of earth connections which are any better than an ordinary iron pipe combined with imprisoned moisture held by natural salts. Where an earth connection is intended to carry heavy dynamic current, as, for example, at the neutral of a grounded generator, the nature of the problem is not changed. It is simply necessary to add sufficient area to carry the maximum dynamic current without reaching the density of current which will dry out the earth around the pipe. In such a case it is usually desirable to feed in salt water from time to time in order to keep such earth pipes thoroughly soaked. The use of several earth pipes at a distance of six feet or more apart, to reduce the earth resistance, is now a well-known practise. The chemical action of the salts in wearing out iron pipes is sometimes mentioned as an argument against the use of salt. In a number of test samples it was found that the corroding action of the salt on the pipe was of negligible value even after a number of years of use. Even under the worst condition of corrosion, it is better to permit it and have a good earth connection than to preserve the metal against corrosion by keeping it dry and having, continuously, a very poor earth connection.

OVERHEAD GROUND WIRES AS AN UNSOLVED PROBLEM

Little by little the last few problems in the protection of apparatus are being solved. This work is being done by the manufacturers of electrical apparatus. The prospects are bright for reaching, in the near future, the condition of insulation and protection in transformers and generators such that nothing but negligence will cause damage to the apparatus. All conditions of protection are at present so much better in stations than they are on the lines that interruptions are almost invariably due to

damage to some point on the transmission line. It has been patent for a number years that the protection of lines is not being sufficiently studied to produce a suitable engineering advancement. No single company has been willing to expend the money to obtain the apparatus and the rarely developed talent for the investigation of lightning phenomena on transmission lines. As a matter of fact there have been no devices made as yet which will give accurate information regarding the localization and distribution of lightning potentials along a line. There was required for this primarily a recorder which would simultaneously and quickly record the discharge of electricity at or near many insulators. One part of the outfit necessary to study the efficiency of overhead ground wires is now to be found in the device called the "multi-recorder," which is on exhibition and in operation at this meeting. There are still lacking the necessary interest and co-operation among transmission systems to organize a scientific attack on this problem. The recently developed possibility of making accurate studies of the value of overhead ground wires is earnestly brought to the attention of the members of the Association. Many thousands of dollars are being invested every year in overhead ground wires. There is little doubt that where they have been installed they have been of sufficient value to warrant their cost. There are, however, many places where the conditions of installation do not warrant the use of the overhead ground wire. For example, in the case of 2300-volt lines on wooden cross-arms situated inside the limits of a city. At the other extreme, there are probably many places where the use of several overhead ground wires would be fully justified. Expenditures for constructions are made somewhat blindly, and no attempt is being made at the present time to get a technically correct solution of this problem.

It is evident that at present transmission lines are inadequately protected against lightning. As the demands for continuous service become more and more exacting this difficult problem will recurrently bring up factors for consideration. Will the present construction of poles and towers lend itself economically to the use of additional protective devices as yet of an unknown nature? What is the most favorable division of investment in steam auxiliaries and extra line construction? In how many

ways does lightning attack a line? Is there any possibility of insulating or protecting a line against lightning?

These are some of the problems to-day demanding solution.

THE CHAIRMAN: We will now hear the Report of the Committee on Operation of Water-Power Systems, by Mr. D. B. Rushmore, of Schenectady.

REPORT OF THE COMMITTEE ON OPERATION OF WATER-POWER SYSTEMS

The problems of operation of hydro-electric systems naturally divide themselves into, first, those of normal operation; second, those of emergency conditions.

The method of operation of a hydro-electric system and the lay-out of the system for such method as may be determined upon, depends upon many factors, some of which are—the relative importance of the different stations, the number of power houses on the system and the relation of each to the whole system, the location and character of the load, the number, capacity and location of the steam reserve stations, and, in general, whether the high-tension line is a purely transmission line, a high-tension distributing circuit, or both.

Naturally, the object of operation is to deliver electric power with the maximum degree of reliability as is warranted by the price paid for power, by the competitive situation, and by the permissible investment in reserves and duplication.

It has become somewhat hackneyed to say in discussing engineering matters that every case is special. In hydro-electric systems, while this is also true, certain broad principles of operation are, however, generally decided upon when designing the system.

The normal conditions of operation are determined largely by the capacities of the different generating stations, by the water conditions and by the characteristics of the load curves which must be met. Practically no hydro-electric development with the capacity of installed apparatus above the rating at minimum stream flow is attempted without a steam station on the same system. This steam station may serve any one or all of three purposes; first, as an auxiliary station to be used at periods of low water; second, as a reserve in case of interruptions; and third, as a regulating station to take care of the variations in the load with the hydro-electric plant running at constant output.

The normal problems of operation, such as starting up the system, paralleling the generators and the power stations and properly dividing the load among them, of putting units into service previous to the demands of the load conditions, of regulat-

ing the voltage for the proper distributing points, of connecting the high-tension lines, and, in general, of so manipulating the generating, transforming and switching apparatus as to deliver the desired load at the distributing centers, with the desired characteristics: these problems are met only after a careful study of what is wanted, by so laying out the power station system of connections, the apparatus and the transmission lines so as to accomplish the desired object.

The object being to give reliable service, consideration must also be given to the cause of disturbances and the means for minimizing their effects. These are abnormal or so-called emergency conditions, and in treating of them, the failure of every piece of apparatus and part of the system must be considered as a possibility, and a definite plan worked out for limiting the magnitude and area of such disturbances.

By far the larger majority of high-voltage systems are really distributing rather than transmission systems, so that one of the principles involved is to localize the disturbance and quickly isolate it. In fact, it might be stated as a general principle that the object to be attained in the design and operation of a power-transmission system, with a view of furnishing reliable service, is to so arrange and subdivide the system that a disturbance in one part will not affect the whole, and that such disturbance will be immediately localized within the least possible limits in such manner and time as not to cause an interruption in the operation of the entire system, and also to remove the cause of such disturbance and within the shortest possible period of time to replace the disturbed apparatus in operation on the system again.

Naturally, the design of a hydro-electric system begins with the consideration of the proper number of generators, transformers and outgoing lines, and when deciding on these the methods of operation of the system as a whole must be kept in mind. With units of large capacity and with several power stations tied into the same system, unusual precautions must be taken to prevent the concentration at points of trouble of too great amounts of energy, and thus the use of artificial and inherent power limiting reactances becomes an important factor.

The complicated high-tension networks to be met with in many places make difficult the manual operation of the system in times of disturbance, and necessitate that automatic high-

tension switches be considered for isolating line disturbances. This involves considerations of doing high-tension switching, which has been proven in some cases to be a source of danger to the transformers.

Thus, with the problem of number of units, subdivision of system, characteristics of apparatus, etc., the question of automatic protection by means of proper application of switches and relays is very seriously involved.

In the operation of hydro-electric systems it is naturally the apparatus which is most important, and a short discussion of the salient features of interest in connection with each class of apparatus concerned will therefore first be given.

WATER-WHEELS

In recent years a rapid evolution has taken place in the design of water-wheels, the most marked being the increased application of single-runner, vertical shaft turbines to low heads, where previously multi-runner turbines of either the horizontal or vertical type were used. This has been made possible by the progress in the design and development of high capacity runners, so that for a fixed head and capacity it is now possible to operate modern runners at much higher rotational speed than was possible with runners of older designs. This increase in the power of runners has furthermore been obtained without any sacrifice in the maximum efficiency of the wheel and with only a slight sacrifice at partial loads.

In low-head installations where it would be practicable to install water-wheel units of either type, the single-runner turbine has a number of advantages over the multiple-runner. For example, only one gate operating mechanism is required and this is located above the head cover of the turbine and is thus accessible at all times for inspection, while repairs can readily be made to this mechanism without dismantling the wheel. A better design of the draft tube is made possible with a single-runner unit, and it is possible to mold in the concrete a spiral turbine casing similar in design to the cast-iron spiral casings used in connection with high-head turbines, which, of course, would be impractical with more than one runner.

In the case of a vertical turbine having more than one runner, the depth and consequently the cost of the substructure

of the power house is necessarily much greater than in case of a vertical single-runner turbine, and the cost of erection and dismantling for repairs is considerably less in the case of the vertical single-runner wheel.

Very exhaustive and accurate efficiency tests of two 6000-hp. vertical single-runner turbines, having concrete spiral casings and ideal draft tubes were recently made, and showed an average maximum efficiency of 93.7 per cent. With the excellent results so far obtained by this type of wheel, it is safe to predict that it will be used almost exclusively for low-head developments.

In deciding upon the number and capacity of the units in a station, the combination of the water-wheel and the generator must necessarily be considered together. Besides hydraulic conditions and the limitations of the water-wheel design, it is governed by the load-factor, the nature of the load, the reserve capacity, the reliability and flexibility of the service, etc. The units should be operated as near full load as possible, and new units should preferably be started as the load increases instead of utilizing overload capacities. Where sudden overloads of considerable magnitude come on the system for short periods it is, of course, necessary to have wheel capacity sufficient to care for them. Single units are never desirable except for multiple-plant systems, in which case the necessary reserve can be obtained from other stations. For single-plant systems the number of units should preferably not be less than four, but above this the number should be governed by the limit in design, considered both from a technical and an economical point of view. With a small number of large units the first cost, the maintenance charge and the necessary floor space are reduced, and the efficiency is also usually better than for a larger number of smaller units.

GENERATORS

The generators should have a rating corresponding to the point of maximum efficiency of the water-wheel, as the efficiency of the latter, especially for low heads, falls rapidly above and below this point. It is therefore desirable to operate the wheels near their maximum output, leaving only a small margin for regulating purposes, and the generator should then preferably be given a maximum or constant continuous rating corresponding to the water-wheel.

The A. I. E. E. Sub-Committee on Rating of Electrical Machinery has also recently recommended that generators should be rated upon a basis of ultimate temperature without other limits of capacity being exceeded, and furthermore that no overloads be specified except momentary overloads. These should not be less than 150 per cent of the rated current, should be without regard to the rated voltage, and should not exceed 60 seconds.

A maximum ultimate temperature of 90 deg. cent. is recommended for machines having the coils insulated with cotton, treated cloth, paper, and similar substances which may fall in this general classification. It is also recommended that the room temperature on which tests are to be based should remain 25 deg. cent., this having been found to be the average temperature of the cooling medium in which generators are operated in practice. It is, however, found that the cooling medium may vary widely in temperature, and may, in poorly ventilated places, and in locations influenced by other conditions, run as high as 40 deg. cent., even though the outdoor temperature be lower. For this reason it is recommended that 40 deg. cent. be recognized as the upper normal limit of the cooling medium and that temperatures higher than 40 deg. cent. should be accepted as abnormal conditions and require special consideration.

With the above stipulation it is, therefore, recommended that a constant continuous rating of alternating-current generators should be based on a temperature rise not exceeding 50 deg. cent, the room temperature being taken as 25 deg. cent. This will then leave a 15 deg. cent. margin for variation in the temperature of the cooling medium before the ultimate temperature, which would be injurious to the insulation, is reached.

With large generating units the question of ventilation becomes of great importance and is now given very careful consideration both in connection with the design and the location of the machines. Instead of allowing the paths of the air to be determined by chance, the air is, wherever possible, drawn from over the water in the tail-race and, in some cases, passed through cloth filters. The air is drawn up into the generators, either by forced ventilation or by natural ventilation created by the generator itself. By designing the generator so as to properly direct the paths of flow of the air, a very marked improvement is made in large generators, and by taking this air from the cool

space over the tail-race it has, in some cases, been possible to reduce the temperature of the machines up to 20 deg. cent.

In the line of operating the generators within safe limits it has now also become good practise to place a temperature coil in the hottest part of the armature from which leads are taken to an indicating device on the switchboard, so that the operator can tell at any moment the maximum temperature to which the armature winding is being subjected.

In comparing the guaranteed efficiencies of several makes of generators, care should be taken that they are based on the same assumptions. The efficiency of the generator is the ratio of the output to the input and should always refer to the energy rating at the true operating power-factor. In certain instances the efficiencies are based on the apparent kilovolt-ampere rating, but the inconsistency of such a method, which would give higher results, is apparent.

While naturally both 60 and 25-cycle generators are being installed as conditions determine, the increase in the size of the individual units has made it desirable to design a large number of these for 11,000 and 13,000 volts. Very satisfactory results are being obtained by grading the insulation, and the slight corona effects noticeable on some coils at high altitudes is now readily taken care of by proper design of the insulation.

A general agreement has been reached to consider the maximum runaway speeds of water-wheel driven units at 100 per cent increase, in order to have a standard applicable to the majority of cases.

Brakes are being installed in a number of cases in connection with vertical units, but so far as is known they have not been used in connection with horizontal units and their use can hardly be considered standardized.

Considerations of safety for the apparatus have led to the development of generators with a comparatively high inherent reactance. This is naturally obtained by sacrificing a close inherent regulation of the machine, but this does not prevent a good regulation on the system from being maintained, the same being accomplished by means of automatic voltage regulators.

Three-phase generators should always have their armature windings connected in star. Whether the generator neutral should be grounded or not depends on operating conditions. If

an uninterrupted service is the most essential consideration, the system should not be grounded, while if it is more desirable to limit the voltage strains, imposed by grounds, it may be advisable to ground the neutral, thus limiting the stress to the Y-voltage. Grounding may also be advisable where selective action is desired on a number of outgoing feeders, especially underground, so that individual feeders may be disconnected even in the case of grounds. In transmission systems with one or two lines the isolated system seems to be the most favored and the apparatus must therefore be designed to withstand the full delta-voltage. If this is not advisable the neutral must be dead-grounded, but in this case the mechanical design of the apparatus must be such that it can safely withstand the strains due to the frequent short-circuits which occur when ground takes place. If the grounding is done to insure selective action of feeders, it may be advisable to ground the generators through a resistance. In this case, however, the voltage strain is not limited to the Y-voltage and this must be given due consideration. The resistance should have a value high enough to limit the neutral current, but still low enough to insure that, if a ground occurs in one phase, it will permit a sufficiently large current to flow in the neutral to open the protective circuit-breakers. Non-inductive resistances are preferable to reactances, since they eliminate the danger of high frequency oscillations between line and ground through the generator reactance in the path of the third harmonic, by damping the oscillation in resistance. The grounding of the neutral through a reactance may, therefore, be very dangerous, owing to the possibilities of a resonance voltage rise.

EXCITERS

While comparatively little attention has been paid in the past to the problem of excitation, a great deal is now given to this important subject. The capacity of the exciter units, the proper division of the required exciter capacity into several units, the method of drive, the arrangement and connections of the different units, the proper system of automatic voltage regulation, etc., are all factors which should be given careful consideration, and which have an important bearing upon the successful operation of the plant.

The capacity of the exciters should be sufficient to excite all the synchronous apparatus in the station when these machines

are operating at their maximum load and at the true operatin power-factor. It is not enough to provide for the excitatio when the machines are operating at unity power-factor, becaus the excitation required at lower power-factors is consider ably higher than at a unity power-factor. Exciters are gen erally designed for a 25 per cent, 2-hour overload rating and b providing exciters with a combined normal capacity equal to th excitation required for all the synchronous machines in the st tion when operating at the maximum load, sufficient margin wi be left for operating auxiliary apparatus as the case may be.

A 125-volt excitation pressure has been considered standa for moderate size installations, while for larger plants a 250-v exciter system will generally be found more economical.

Almost all exciters are now of the direct-connected ty They may be driven either by the main generators, by separate water-wheels or by motors. The practice of installing one direct-connected exciter for each main generator has been used considerably in the past, although in modern installations it has generally given place to other systems. With a few generating units in the station, however, this method may be used, but in order to provide for the failure of one exciter it is advisable to give each exciter a rating equal to twice that required for one generating unit. For plants with a large number of units, this system, however, becomes rather complicated and it is furthermore open to the objection that the exciters will be affected by the speed variations of the prime movers caused by the variation in the load.

The system which seems to be the most favored from an operating point is one in which the excitation is obtained from a common source consisting of as few exciters as possible. Three units are then generally provided, two of these being used fo normal operation and the third one being held in reserve. Ther seems to be some different opinions as to whether the two excite used for normal operation should be water-wheel driven and reserve unit motor driven, or vice versa. It seems, however, t both from an economical point of view and from an opera standpoint, it would be preferable to have the two exciters for normal operation motor driven; the water-wheel driver citer should then be used only when starting up or as a re This method seems therefore to be the most desirable, as

is always a possibility of debris clogging up the small exciter turbines, while on the other hand it is claimed that motor-driven exciters will operate more satisfactorily in parallel, this being partly due to the fact that it is difficult to provide a sufficient fly-wheel capacity with water-wheel driven units without equipping them with fly-wheels. Preference for motor-driven exciters has been given in one particular instance for the reason that on short-circuits in the system, the motor-driven exciter sets will drop in speed and thus minimize the effect of the short-circuit.

In some of the latest hydro-electric developments an entirely new and quite novel system of excitation is being used, in that one small motor-driven exciter set is provided for each generator unit. The exciter has a capacity corresponding to that required by its generator and the terminals are connected directly to the generator field. The motors of the various exciter sets are fed from one or two low-voltage generators driven by independent water-wheels, but in addition, the connections are so arranged that if necessary the motors may be connected to the main bus through transformers, two separate sources thus being provided for driving them. With this arrangement the objection to motor-driven exciters on the ground that they are liable to fall out of step when the short-circuit occurs on the system, has naturally no bearing, because the system of excitation is entirely independent of the alternating-current system.

Another large development also uses a system somewhat similar to the above, but instead of making provisions so that each individual exciter set may be connected to the main bus, the auxiliary water-wheel driven generators normally feeding the exciters are also direct-connected to an induction motor which can be connected to the main bus in case of trouble to the water-wheels.

The use of storage batteries in connection with exciters has of late been increasing considerably. The advantages of such a combination are obvious, as, with the failure of exciters for some reason or other, the storage battery would automatically keep up the excitation.

TRANSFORMERS

The number and size of the transformers and whether they should be of the single or 3-phase type, depends entirely on the

nature of the development and on the conditions to be met. With moderate voltage developments it has in the past been the general practise to install one transformer bank for each generator and of equal capacity to the same, even if this size was not the most economical. With a large number of units it was then naturally more advantageous to install 3-phase transformers, while in plants consisting of one or two generating units where the cost of a spare 3-phase transformer was not warranted, it was found preferable to install single-phase type units.

With our present modern high-voltage systems where it is undesirable to parallel the transmission lines on the high-tension side or to carry out any high-tension switching, it has become general practise to install the transformers in groups, each having a capacity corresponding to a line; the transformer group and the line thus being considered as a unit. Transmission lines generally have a current-carrying capacity ranging from 15,000 to 40,000 kw. and as the most economical size of high-voltage transformers is from 6000 to 10,000 kw., it is obvious that it is entirely feasible to provide one bank of single-phase transformer for lines up to about 25,000-kw. capacity, while above this, it becomes necessary, as a rule, to provide two banks in parallel for each line. The transformers may be connected either in delta or in Y, but it is now generally conceded that the isolated delta connection is preferred on account of the increased reliability which such a system affords. Under normal operation the voltage stress of the apparatus is the same whether the isolated delta or the grounded Y-connection is used, but in case of ground on one line wire the isolated delta system will naturally be exposed to a higher voltage above ground than would be the case with the grounded Y system. The disadvantage of the grounded Y-system, however, is that any ground of the line wires will cause a short-circuit and thus a shut-down, which is not the case with the delta system, where in certain instances it has been found that the operation could be kept up for a whole week with one of the line wires grounded.

The most important requirement in connection with modern transformers of large capacity is, that their design must be such as to limit the current output of the system which it feeds at times of short-circuits, and besides this to successfully withstand the tremendous mechanical strains to which the transformer

windings are subjected due to short-circuits. Such transformers are for this reason now generally designed with a considerable higher reactance than was formerly the case; 4 to 6 per cent reactance now being quite common.

The transformers should always be provided with taps in the windings. In many instances it is found desirable to begin the operation of the system at half the ultimate voltage and in order to accomplish this the transformers are often provided with 50 per cent taps in the high-voltage winding. It is also customary to provide the high voltage windings with four 2½ per cent taps below the normal operating voltage so that these taps can be used in compensating for the line drop as the load increases. Such taps are of course only necessary in the step-down transformers, but for the sake of interchangeability they are usually provided in the step-up transformers as well.

The step-up transformers which are located in the generating station are of course always of the water-cooled type. Such is in many instances also the case for substation transformers, although in the majority of cases self-cooled transformers must be used on account of the absence of sufficient cooling water. There are a number of different types of self-cooled transformers on the market such as the corrugated type, the compound corrugated type and the radiating pipe type. A combination of a self-cooled and air-blast type has also been proposed and it seems to be a very feasible arrangement. Such transformers could be operated at the average load as plain oil-cooled transformers, while for peak loads of considerable duration they could be run and efficiently cooled by starting up the blower outfit.

A considerable activity has recently taken place in the use of out-door substations. With the exception of the bushings the transformers for such installations differ comparatively little from the indoor type; the only feature out of the ordinary being the necessity of keeping moisture from entering the transformer cases under the covers and leads. To prevent this the joints have been made with waterproof gaskets and breathing chambers have been provided.

Special precaution must naturally be taken to protect transformers of the outdoor type both from the extreme heat in the summer and from the cold in the winter. While the former can readily be obtained by providing sunshades, in certain instances

very good results have been obtained by simply painting the tanks white. It is more difficult, however, to provide for the cold winter temperatures, especially with water-cooled transformers. With the transformers in service there seems to be no danger of freezing and if such should be the case some sort of heating grids could readily be provided in the bottom of the tanks. The main difficulty lies in the formation of moisture which takes place when the temperature of the transformer is allowed to fall below that of the surrounding air. This applies equally well to indoor transformers, and precautions must therefore be taken that this does not happen. This may be accomplished either by reducing the water rate at times of cold weather or by using the cooling water over and over again. Non-freezing oil may be used in such transformers, but its cost is so high that it is almost prohibitive from a commercial point.

Water flow indicators, oil gauges and indicating thermometers should naturally be provided and it has also been suggested that it would be advisable to insert exploring coils in the transformers and connect them with indicating instruments on the switchboards.

POWER-LIMITING REACTANCES

The increase in the size of modern generating units and the concentration of enormous amounts of power in single generating stations or systems have made it necessary not only to increase the inherent reactance of the apparatus but also to provide artificial reactances for limiting the amount of current that may flow from any part of the system into a short-circuit in apparatus or connections inside of station or close to the station. By so limiting the abnormal flow of current into a short-circuit the generating system, as a whole, is relieved from possible disastrous effects of such short-circuits.

Power-limiting reactances may be divided into three classes—generator, bus-sectionalizing and feeder reactances. The first class is not used to any great extent in connection with water-wheel driven generators, as these have, as a rule, sufficiently high inherent reactance.

Bus-sectionalizing reactances are, however, becoming very generally used in large stations. When a bus becomes so large that for continuity of service, etc., it becomes necessary to divide

it into several sections, reactances may be placed between the sections, permitting any section to draw only part of its load from the adjacent sections; thus limiting the short-circuit current of one section to that of this particular section and in addition the limited amount drawn from the adjacent sections. The buses are generally sectionalized so that each section has a capacity of from 30,000 to 50,000 kw., and the sectionalizing reactances are generally so proportioned that they will limit the current drawn from the two adjacent sections to the short-circuit current of one generator.

Reactances may also sometimes be advisable in tie lines, this type of reactance to be treated the same way as a sectionalizing reactance. It may also be advantageous to install reactances in outgoing feeders, especially in feeders where trouble is liable to occur at frequent intervals, and the suggestion has been made that it would be advisable to provide reactances in all the station feeders supplying power to the auxiliary station apparatus, such as the motor-driven exciter sets, etc.

REGULATORS AND SYNCHRONOUS CONDENSERS

The problem of voltage regulation has become of increased importance and it has been necessary to resort to new methods to accomplish it, in connection with our modern systems of higher voltages.

The use of automatic T. A. regulators is well understood and this type of regulator has given entirely satisfactory service where it has been applied. While the general practise has been to adjust the regulator for a constant bus-bar voltage in the generating station, compensation for a line drop can and has been obtained by providing line drop compensators. This method is entirely feasible where all the power is fed to one distributing center and where it is desirable to keep the voltage constant at this point. In systems wherever power has to be fed to a number of distributing centers, it is impossible to compensate for the different drops to the various substations.

Where separate exciters are operated for each generator and these exciters are not operated in parallel, as is the case in some modern hydro-electric stations, the regulators can be used for preventing wattless cross-currents flowing between the generators. This is accomplished by installing current transformers

for each generator and by connecting them 90 deg. out of phase with the potential transformer; so that if cross-currents tend to flow between the generators they will be reduced by the regulator action which tends to strengthen or weaken the excitation of the units as required.

The fluctuating voltage of the exciter bus-bars, caused by the use of automatic voltage regulators, is sometimes objected to in cases where it is desired to operate station lamps, oil switches, relays and other auxiliary apparatus from the exciter bus-bars. It is, however, possible to keep the exciter bus pressure constant and effect the voltage regulation necessary for the regulation of the alternating-current generators by means of a booster controlled by an automatic regulator.

A relay has also been devised for use in connection with automatic T. A. regulators for minimizing the effect of short-circuits and possible voltage rises in the transmission system. If a voltage regulator is used and a short-circuit should occur somewhere on the system, the action of the regulator would naturally be to deliver the maximum excitation so as to keep up the voltage of the system. This in turn necessitates that the governors of the prime movers be wide open, and if the short-circuit should be suddenly relieved, the voltage often rises to very high values owing to the time element involved in closing the governors and in demagnetizing the fields. The relay is provided with a current coil and a potential coil and will automatically reduce the excitation in case of excessive loads, high voltages, or any other cause tending to increase the voltage.

The question of regulation of large high-voltage systems involves, as previously stated, a number of difficulties not encountered in low-voltage work. In the latter case the energy loss is generally the limiting factor and the regulation can often be improved by installing larger conductors, which at the same time will reduce the line loss. With high-voltage systems the gain of doing so is very slight and other means must be resorted to for keeping the regulation within commercial limits. The effect of the inductance and capacity of the line causes the voltage to vary within very wide limits from full to no load. At no load the large capacity current causes a rise of voltage from the generating station to the receiving end, while at full load the lagging inductive current taken by the load, in general, more than offsets

the effect of the capacity current and causes a drop of voltage from the generating station to the receiving end. It is evident then that by installing a synchronous condenser at the receiving end, and taking advantage of the characteristics of this machine, the receiving voltage can be kept constant at a determined value by adjusting the synchronous condenser field, causing the condenser to draw a lagging current from the line at no load and a leading current at full load. The generating voltage should preferably be kept constant by means of automatic T. A. regulators.

An automatic regulation of the condenser field current can also readily be accomplished by means of a T. A. regulator. As the excitation must at times be practically zero, a special exciter arrangement must be resorted to in order to provide for the limiting voltage range of the regulator. This is accomplished by exciting the condenser from a 250-volt exciter, whose fields in turn are separately excited from a 125-volt source, consisting of two small exciters which are running series bucking. One of these exciters is designed for 125 volts and the other for 250 volts, the regulator being placed across the 250-volt exciter. In this manner the range of the regulator is from 125 to 250 volts, never reaching zero, while the excitation of the condenser is from zero to 250 volts.

SYSTEMS OF CONNECTIONS AND SWITCHING EQUIPMENT

In laying out the system of connections and the switch equipment for a high-tension transmission system there are a number of general principles which must be kept clearly in mind. Reliability and continuity of service are the main considerations, but besides this the protection of the apparatus from injury should be given very careful study. These considerations, are, however, very closely connected and must naturally be treated together.

While modern methods of design have reduced apparatus troubles to a minimum, they naturally will occasionally occur and it becomes therefore essential to so lay out the system that the troubles may be isolated and not spread and cause a shutdown of the whole system.

The system of connections obviously depends on the conditions, and entirely new methods have to be followed for the modern developments using very high transmission voltages—

50,000 volts and above. The reason for this is, as previously stated, the surges set up by high-tension switching and the dangers to the transformers resulting therefrom, which makes it desirable to reduce all the switching on the high-tension side to the absolute minimum.

The generators should preferably be paralleled on a common low-tension bus, the generator switches being non-automatic, or if automatic protection is desirable the switches should be provided with definite time-limit relay, set very high. Reverse power relays are also occasionally installed, but are generally arranged to ring an alarm gong in case of reversal of the power and not to trip out the switch.

The low-tension bus should, as previously stated, be sectionalized if the capacity of the station is large, it being the usual practice to limit the normal capacity of each bus section to from 30,000 to 50,000 kw. In this connection it may also be advocated that it is highly desirable to so sectionalize the bus that sufficient generator capacity to furnish the charging current of one line can be entirely separated from the rest and used for testing out the lines. A ring bus will generally insure sufficient flexibility to accomplish this, although for larger system a double bus may be warranted.

The inadvisability of tying the high-tension lines together and of high-tension switching, has already been taken up, as well as the preferable grouping of the transformer forming units with the lines. All the switching should therefore be done on the low-tension side of the transformers both in the generating and substations; the former switches being equipped with inverse time-limit relays and the latter with reverse-energy relays.

It is, however, customary to provide non-automatic oil switches in the outgoing and incoming lines to be used in case of sectionalizing and in addition non-automatic tie switches should also be provided between the lines, or if more than two lines are present it may be advisable to provide high-tension transfer buses. Sectionalizing switches of the knife-switch type should be installed at certain intervals on the towers along the line so that the circuits may be sectionalized in two or more sections to facilitate testing and for isolating line troubles.

With this system of connections considerable responsibility is placed on the operators, as the relays of the transformer switches

ust be set at from 100 to 150 per cent overload, thus above the fe continuous operation of the transformers. Suppose, for example, that we have a system with two parallel lines connected two transformer groups on the unit principle. A trouble in e of the lines will then cause it to be disconnected together th the transformers through which it is fed. This then throws the load over to the remaining line, which, with its transmers will be overloaded 100 per cent, and in order that this e shall not be disconnected at this increase in the load, the ays must be set for more than 100 per cent overload. Transmers can, however, carry 100 per cent overload for five or ten nutes, which should give the operator sufficient time to dismect the defective line and connect the transformers in paralagain to feed the remaining line. It is therefore also desirable so proportion the line conductors that one line or one line and a rtion of the other can take care of the entire load, although in h cases a rather poor regulation is to be expected.

All of the outgoing substation feeders should be equipped th switches actuated by instantaneous overload relays so as to mediately disconnect a feeder when trouble occurs in it, and is not cause the trouble to spread to other parts of the system.

Where it is desired to protect against short-circuits, etc., in es tying two generating stations together, the so-called tiee relay should be used. This relay does not operate on overd or on normal reversal of power in the tie line, as the object this line generally is to let power be interchanged between two stations in either direction as the case may be. If a rt-circuit takes place in the tie line, current will then necesily flow from either station into the short, and thus in opposite ections in the sections on either side of the trouble. It is on s principle that the relay is designed and under this condition will cause the tie-line switches to trip at both ends of the e, thus cutting it out of service without disturbing the operation the two stations. This relay is also termed a "pilot-wire" ay as it necessitates the use of pilot wires between the stations its operation.

In selecting the oil switches their rupturing capacity becomes importance. A smaller size switch can as a rule be used ime-limit relays are used, as this permits the initial short-circuit rent rush to diminish before the switch opens. It should also

be kept in mind that smaller switches can oftener be used at the substations than at the generating stations, because the reactance of the transformers and the transmission lines will reduce the short-circuit currents and their effect to a great extent.

LIGHTNING ARRESTERS

Aluminum-cell electrolytic lightning arresters are nowadays used almost entirely for lightning protection of high-voltage transmission systems. This type of arrester has an enormous discharge capacity, and its general characteristics are well known. The arrester, however, is not a universal protector against all kinds of interruptions. For example, while it meets the usual, and most of the unusual, needs in protection against disruptive potentials from lightning, an arrester located in the station can not, and is not expected to protect an insulator out on the line from a lightning flash. Neither is it designed to protect against surges of relatively low potential.

The comparatively recent addition of a charging resistance will insure a material improvement in the operation of the arrester, as well as increased life of cones and electrolyte. The charging current is limited, and its wave form is so modified that, even with such a delicate test as a parallel telephone circuit, it is impossible to detect any action of the charging on resonant parts of the circuit.

The horn gap with charging resistance has an auxiliary horn mounted above and insulated from the regular horn in such a manner as to intercept the arc if it arises on the regular horns. Enough resistance is connected in series with this auxiliary horn so that the current flow and arc across this gap are always limited to a moderate value. Such a device has several advantages. Since the mechanism is so arranged that the charging is always done through the auxiliary horn the current rush is limited during the charging and thus troubles from carelessness or ignorance are avoided. It also gives a more uniform charging current. Light discharges will pass across the auxiliary gap through the series resistance to the cells. If the discharge is heavy, the resistance offers impedance to cause the spark to pass to the main horn. This is accomplished with only a slight increase in potential because the gap is already ionized. If the cells are in a normal condition the spark at the gap is immediately extinguished

without any flow of dynamic current. If the cells through either iegligence or some untoward condition are in poor form, the ynamic current may follow the discharge across the main gap id the arc will rise to the safety horn and be extinguished rough a resistance.

It is important to avoid the mistake of choosing an arrester ir a thoroughly grounded neutral when the neutral is only partly ounded; that is to say, grounded through an appreciable re-stance. Careful consideration of this condition will make the ove statement clear. In an arrester for a grounded neutral cir-iit, each stack of cones normally receives the neutral potential hen the arrester discharges; but if a phase becomes accidentally rounded, the line voltage is thrown across each of the other acks of cones until the circuit-breaker opens the circuit. Line oltage is 173 per cent of the neutral or normal operating volt-ge of the cells and therefore about 150 per cent of the perma-ent critical voltage of each cell. This means that when a rounded phase occurs, this 50 per cent excess dynamic potential i short-circuited through the cells until the circuit-breaker opens. he amount of energy to be dissipated in the arrester depends pon the kilowatt capacity of the generator, the internal re-istance of the cells, and the time required to operate the circuit-reakers. It is evident that the greater the amount of resistance i the neutral, the longer will be the time required for the cir-uit-breakers to operate. Therefore, in cases when the earthing esistance in the neutral is great enough to prevent the auto-natic circuit-breakers from opening practically instantaneously, n arrester for a non-grounded neutral system should be in-talled.

It is difficult to determine these factors of ground resistance nd time elements in the operation of switches and therefore no nistake can be made by adopting the 4-tank arrester even on rounded Y circuits.

Aluminum-cell arresters have been used for both indoor and utdoor service, but experience seems to indicate that the best ervice is obtained by indoor installation, in which case it is usual place the tanks indoors, while the horns are placed outdoors. luminum arresters operate with increased life and maximum effi-ency at moderate temperatures. Below 20 deg. fahr. the elec-olyte freezes, increasing its resistance considerably and tem-

porarily decreasing the discharge rate and hence the efficiency of the arrester. The electrolyte and cells are, however, not injured by this freezing. On the other hand, during the periods when arresters are frozen, the troubles from lightning are practically *nil* and the troubles from surges are at a minimum. Consequently there is not as much need at these times for the highest degree of protection.

At high temperatures such as would be experienced from exposing the tanks to the direct rays of the sun, the electrolytic film on the cones is more rapidly dissolved, hence requiring more frequent charging of the arrester to keep the film in proper condition. This dissolution becomes more rapid as the temperature increases. Operation at temperatures above 100 deg. fahr. necessitates more frequent charging and continued operation at these temperatures results in decreased life of the electrolyte and cells. High initial temperature of the oil and electrolyte is undesirable, as the heat storage capacity of an arrester decreases with increased initial temperatures. This condition reduces the time which an arrester can continue to discharge heavy recurrent surges.

For these reasons the outdoor installation of aluminum arresters cannot be considered as desirable as the indoor, but the conditions may be such that it is very essential from an economical point to locate the arresters outdoors, in which case means should be provided for shading them from the direct rays of the sun. During the past few years a large number of arresters of various voltages have been installed outdoors, and their operation has been quite satisfactory.

MISCELLANEOUS PROTECTIVE APPARATUS

A number of other protective devices have been used with more or less satisfactory results. Among these may be mentioned the electromagnetic, arcing ground suppressor and the short-circuit suppressor. The former is intended for extinguishing arcing grounds such as insulator spill-overs, etc., before such grounds have had time to do damage and cause a shut-down of the system. This device consists of an electromagnetic phase selective relay and three single-pole oil switches or fuses which are connected between each conductor and ground. Besides these there are, of course, a number of auxiliary devices. In case one phase becomes grounded, the equilibrium of the

relay is immediately disturbed, and it causes the oil switch connected to the grounded phase to momentarily close, thus dead-grounding the conductor, which shunts the arcing ground and extinguishes the same, after which the oil switch immediately opens again. When fuses are used in connection with the relay, the action of the relay causes these fuses to be connected between the line and ground in case of trouble. The time element of this dead-grounding is obtained by the blowing of the fuse.

The action of the electromagnetic short-circuit relay is somewhat similar, but it is of course connected between the phases instead of between phases and ground. The time during which these devices have been in service has been too short to demonstrate their usefulness.

Another device used is the so-called "generator-field destroying and restoring device," which is designed for protecting the generators and station apparatus from extended short-circuits or grounds. The function of this apparatus is to reduce the excitation of the generators for a short period when short-circuits or grounds take place, the excitation being restored after two or three seconds, which period is so short that there is no danger of the synchronous apparatus falling out of step.

TRANSMISSION AND DISTRIBUTING LINES

On account of their exposed position, the transmission lines are possibly the weakest link in the high-tension transmission system, and even the failure of a single insulator may cause a complete shut-down of the system. It is therefore necessary that very careful consideration be given to the design and erection of such lines.

In general, steel towers should be used for all high-tension transmissions of a permanent character, as they insure an increased reliability which is a feature of special importance where there is competition from unfailing steam plants located in the same field of distribution.

The more important reason for the greater reliability of a steel tower line over one of wooden poles is their substantial construction, which makes them capable of withstanding sweeping storms. Lightning troubles, such as splintered poles, etc., are not present, and towers are, of course, indestructible from forest fires. On the other hand, easy access to either circuit can be

obtained in a double circuit tower, making it possible to keep up service on one circuit while repairing the other. The life of a steel tower transmission would also be considerably longer than that of a wooden pole line.

Both single and double circuit transmission lines are in use, but it does not seem wise to depend entirely upon a single circuit to transmit the output from an important plant. The same weight of copper divided into two circuits and supported by slightly modified towers would considerably reduce the chance of shut-down with only a moderate additional cost for towers, a second set of insulators, and the labor of stringing the second circuit. Independent tower lines with either single or double circuits may be advisable for the very largest and most important installations, and in such cases it may be advantageous to let the lines pass over entirely different routes, especially in mountainous regions, so as to minimize the possibility of shut-down occasioned by storms, land slides, severe lightning, etc.

Wherever it is desired to make the tap from a single line it is advisable to loop the main line into the substation. That is to say, if it is desired to run a tap off a main line about a mile in length, this is made a double circuit, the line being looped in so that the services of the substation attendant can be used for sectionalizing the line in case of trouble. Where taps are to be made from a double circuit line it seems to be the common practise to build a double circuit tap and bring in one tap from each of the lines to the substation. No protective devices are provided where the taps are taken off the main lines, as the tap line is rather considered as a portion of the main line. The reason for this is that the expense of maintaining a switching station at the tap located a few miles from the point of distribution is generally greater than what the additional reliability of service would justify. In systems where branch lines of from 25 to 30 miles are tapped off the main line, the switching apparatus for these branch lines is always located in the nearest town to which the branch line runs, and in some cases this is as much as 10 miles away from the tap.

The right-of-way should be selected, as far as commercial conditions permit, with the view of escaping possible land slides, floods, etc., and avoiding thickly settled districts. Across open country a physical dividing line is usually not made, but this is

of the greatest importance where the line passes through forests, where right-of-way should be cleared of the trees, the clearing being wide enough so that there is no possibility of falling trees striking the line.

Line conductors may be either copper or aluminum. It is advisable for mechanical reasons in spans of 200 to 300 ft. never to use smaller cable than No. 5 B. & S. copper or No. 1 B. & S. aluminum (equivalent No. 3 copper). For spans greater than 300 ft., the minimum sizes of cable allowable are those which will give a reasonable sag at the most severe climatic conditions assumed. Frequently the size of conductors, determined by electrical considerations, limits the length of spans to a smaller value than is economical. This may occur even with moderately long spans—500 to 600 ft.—when the character of the country is such as to make transportation costly or when expensive foundations must be used. In such cases it will often be found that a saving can be made by increasing the size of conductor, thereby allowing an increase in the length of span and the use of fewer towers of approximately the same height and not greatly increased weight.

Experience has shown that the overhead ground wire is of undoubted value for lightning protection, and better results may be expected from two wires than from one. They should be placed as far above transmission wires as practicable and with a maximum shade angle of 45 deg. When concrete foundations are used and the steel work does not extend through to the moist earth, it is necessary to make independent earth connections from a ground wire. This may consist simply of iron pipes driven into the ground and connected to the legs of the tower.

Suspension insulators are now used exclusively for high-voltage transmission lines, the practical limit of the pin-type insulator being approximately 60,000 volts. For transmission voltages higher than are used at the present, the design of the suspension insulator must necessarily be modified, so that the potential along the string can be better distributed. A liberal factor of safety should be allowed in selecting line insulators, as they form only a small part of the total cost of the line and are the most vital factor in its success.

When telephone wires are supported on the towers beneath the transmission line wires, they should be hung in such a position

as to minimize the danger of being crossed by the power cables in case any one of the latter should break. On account of the long spans they should preferably be made of copper-clad steel wire and be hung about 8 to 10 ft. beneath the lowest line conductor and frequently transposed so as to minimize the noise under normal operating conditions. Grounds, etc., on long power circuits of course cause more or less noise in the telephone systems, but by using leakage coils and transformers this can generally be done away with and very good service obtained. For very large systems it seems, however, that separate poles should be used for the telephone line so as to secure an absolutely uninterrupted telephone service, as this is without question one of the most important points in the operation of the system.

OUTDOOR STATIONS

The necessity for reducing the investment outlay and the fixed charges, especially with small substations, has brought about of late a rapid development in out-of-door substations, and especially those at which the operator may be dispensed with. In such cases it is desirable to have fuses or automatic switches to cut off the substation entirely in case of local trouble.

With the higher voltages and the necessity for greater clearance and spacings, the saving in outdoor installations becomes considerable, and the limit regarding their use has not by any means been determined.

In places of severe winter climate small outdoor substations with oil-cooled transformers have worked satisfactorily except in cases of repair, and, especially in the larger installations, provision must be made for repairing the apparatus indoors. It is, as previously mentioned, possible to introduce auxiliary heating apparatus into transformers and switches, and also to use an oil which does not freeze except at extremely low temperatures. This, together with the possibility of lagging apparatus with a heat insulating covering, gives a large degree of independence as regards climatic conditions.

Under severe climatic conditions there is, in general, more of a hazard in placing the apparatus out of doors than indoors, and it is a matter of judgment to decide between the saving in cost and the extra risk involved.

NORMAL OPERATION

The selection and maintenance of an efficient and reliable operating force is without question one of the greatest insurances for satisfactory operation. Most modern systems of any size have a method of operation which corresponds to that of a train lispatcher on steam railroads, and where many different plants ire attached to the same network this becomes practically necesary. The directions of operating the different stations and apparatus come from a central source, where the chief operator as before him a diagram of the entire system and information egarding the capacities of the generators in use and of the magitudes of the loads at the different places of distribution.

The successful operation of a large system is therefore inimately connected with the means which are provided for comnunication. Elaborate signal systems are being installed in the ower houses and telephone lines are always installed between e different stations. The use of the telephone service is espeially important at times of electric disturbances, thus at the me when there is the greatest danger that communication may : interrupted, and for this reason the greatest care must be :ercised in the routing and erection of these circuits. It generly means independent pole lines; and the use of wireless comunication has also been advocated, although it is not known iether it has ever been actually tried out.

All systems have to some extent momentary fluctuations in e demand for power, and one or more daily peaks in the load cur. Some provisions must be made for taking care of both these, and this is done in many ways in the different systems operation to-day.

In the larger hydro-electric systems there are usually some ants which have storage, and others which do not, so that a istinction in operating these is well made by having the storage lants do the regulating for the system; and, as in the Boulder lant of the Central Colorado Power Co., this is sometimes rried to an extreme and the plant installed to simply carry e peak of the load.

The regulation of water-power systems is as a whole worked it in various ways, but, as a rule, one plant is generally selected r this particular purpose.

The switching operations are determined by the general thod of operation. It has, however, been previously advo-

cated that all high-tension switching under load should be entirely abolished, but where necessary, the apparatus should be so arranged as to have as large a capacity as possible left in position behind the rupture to absorb the electrical disturbances.

When, for example, a line is to be cut into service, the high-tension switches in both the main and substations should be closed first, then the low-tension transformer switch in the generating station should be closed, energizing the transformers and the line, after which the low-tension transformer switch in the substation is closed and the load picked up. In case it becomes necessary to open a high-tension switch in a loaded line, the circuit should if possible first be paralleled with another before opening the switch. If on the other hand, transformers are to be paralleled on both high and low-tension sides, the low-tension switch should be closed first, assuming that the low-tension bus is energized. Similarly, in cutting out the transformer the low-tension switch should be opened last.

With the present requirements for large amounts of air for ventilating generators, the amount of dust brought into the apparatus, unless the air is properly filtered, is great, and regular inspection and cleaning at stated intervals is necessary.

The patrol of transmission lines, with the great improvement that has taken place in high-tension insulators, has been very much reduced, and a greater importance is attached to the ability to locate the particular point on the line in trouble, and to get the repair men there at the earliest possible moment. Line inspection at night has also been made possible by the use of acetylene searchlights.

A simplified system of records is being worked out on different power systems which gives the necessary information regarding the units in operation, the condition of the system in its different parts and of the location and magnitude of disturbances.

Mechanical registering devices have also been brought out which show the operation of the different switches, lightning arresters, etc., and the time involved. Such records are of value not only to the commercial organization but are exceedingly helpful, as in the line of educating the operators.

Suggestion systems have been introduced by several operating companies, prizes being given to the men offering the best suggestions. This practise has in many instances been very

satisfactory, many good and valuable suggestions having been obtained and used with profit.

All possible precautions should of course be taken to protect the operators from danger, and the excellent results that have in the past been obtained by "pulmotors" in resuscitation from shocks would seem to indicate the importance of providing some such apparatus in all important stations.

EMERGENCY CONDITIONS

Transmission systems must be designed to meet the emergency conditions which arise, quite as much as those of normal operation. Troubles and interruptions occur in every commercial system, and their results must be minimized so far as possible.

Trouble still arises from breakings in flumes, pipe lines and penstocks, as well as in hydraulic valves, but most of the disturbances are due to line troubles or the break-down of apparatus from the effects of overload or high-voltage disturbances.

Two general principles are involved in the decision as to how to care for such cases. Reliance is placed either on the operators or on automatic devices. Theoretically, the system should be arranged so that the disturbing part or piece of apparatus is automatically cut out as soon as the condition becomes abnormal, and the remainder of the system is left to supply the power.

In many systems the transmission and distribution is subdivided so that a disturbance on one part is spread over the whole system, and occasionally certain customers to whom power is wholesaled are the source of so many interruptions that they are given a separate transmission line and a number of generators set apart for their particular use.

When a whole system is run together in this way, one of the first actions in case of trouble is to subdivide it so far as possible, in case the system is not arranged so that the automatic switches of themselves cut out the disturbances.

The necessities of future large transmission systems will undoubtedly be such that the automatic operation of high-tension switches will be necessary, and the present development in switches and protective apparatus promises to take care of this situation.

In order to prevent the concentration of excessive amounts of power at points of disturbance, generators and transformers are now being designed with high reactance, and artificial re-

actance coils are being used in generator leads, in the bus-bars and in series with outgoing feeders.

Unfortunately, there are certain phenomena of high frequency, but without excessive potential, which need additional means of protection. Careful investigations have indicated that such surges as are set up by arcing grounds, etc., discharge into the transformers where they may cause resonance resulting in internal disturbances which have hereto been unknown. One of the greatest sources of disturbance is still the influence of lightning discharges on the transmission line, and while a great deal has been done to reduce its effects on insulators and on apparatus in the stations, some interruptions are still to be traced to this cause. By the use of overhead ground wires, of protecting rings over the insulators, of arcing rods at the end of the suspension insulator, and shields in various forms on the insulators themeslves, the destructive effects of the discharges have been largely decreased.

The electrolytic lightning arrester has reached a stage of development where it is a nearly complete protection against high-voltage disturbances. It requires, however, very good care, and the charging should be done as the conditions require, or the value of the arrester may be seriously reduced.

Several causes of destruction of electrolytic lightning arresters have occurred due to bad regulation of the lines. In one case the arresters were subjected to 175 per cent of normal potential with considerable generator capacity back of it. This turns an arrester to functioning as a rheostat. An arrester designed to give a high current discharge at abnormal potentials evidently cannot last long if it is made to take power from a large generator, the energy in a lightning stroke or surge being comparatively small.

It has happened frequently that an aluminum arrester, put under a severe discharge for a long period, has shown no signs of failure or distress. The next day, however, when this arrester was being charged, a great tendency to damage by the dynamic current was apparent. This is due to the fact that after the arrester has been in operation for a considerable period as the result of an arcing ground, the electrolyte becomes unusually heated, and the films are dissolved with greater rapidity as the temperature of the electrolyte rises. If all users would

take the precaution of charging their arresters frequently during the time that the electrolyte is cooling down, the films could be maintained in good condition without the destructive currents which take place after the films have stood for several hours in the warm electrolyte. It is one of the strong factors in deciding on the general adoption of the charging resistance.

The causes of interruptions due to transmission line troubles may be divided into three classes, viz., mechanical failure, mechanical failure following electrical disturbances, and wilful damage.

Mechanical failure is due fundamentally to insufficient strength in some part of the construction. It may be caused, however, by accidents which would not have been foreseen, such as landslides, severe floods, exceptionally heavy deposits of ice on wires, either alone or accompanied by very heavy winds. Ordinary climatic conditions may, of course, cause interruptions if sufficient care has not been given to the engineering of the line or faulty material has slipped past the inspector.

The following observations as regards the formation of ice are the result of an exhaustive inquiry:

Ice forms with equal ease on dead or live wires up to an operating voltage of 200,000, above which no reliable information is available. This statement is made on the supposition that there is not sufficient current flowing through the conductors to warm them. The largest ice deposit recorded was one of five pound weight per foot length on a No. 4 B. & S. wire.

Ice clings with considerable tenacity to the line. For example, the line may fall to the ground and the ice still remain attached.

The ice coat may form in a circular or oval-shaped section and with the wire either in the center of the deposit or considerably displaced therefrom, depending on weather conditions. The oval-shaped formation where it occurs with longer axis vertical will give a greater wind area than that usually allowed for in calculations.

The ice may drop off from all the wires on one span and remain on those of the next span, thus giving an unbalanced pull on the towers. This may occur in adjacent long and short spans where certain wind conditions cause surging in the long span.

The ice may drop off from part of the wires in alternate spans, which will cause the loaded wires in the middle span to

sag excessively, in which case they may come into contact with the wires below, causing a short-circuit. For this reason it is now considered better practise not to install the conductors in a vertical plan, below one another; and in new lines the middle cross-arm is generally made longer than the two others.

An aluminum line will collect as much sleet as the copper or steel line. This, though contrary to reports of some observers, is well confirmed and seems to show that the nature of the wire is of no importance in this regard.

It is quite possible for sleet to collect at 32 deg. fahr., and for the temperature afterwards to drop considerably, so that calculations made to determine the maximum stress on the wire should be based on a sleet deposit at the lower temperature. Also, even though sleet storms are not usually accompanied by high winds, the sleet often remains on the wires for several days and during this period it is possible for the wind to rise to a dangerous velocity. Zero deg. fahr. has been arbitrarily chosen as a reasonable minimum temperature to consider in conjunction with ½ in. of ice and an 8-lb. wind.

An ordinarily well-constructed line need not suffer from ice formation. In fact, there are but few cases on record of transmission lines having trouble from this cause, and the reason for this is doubtless that a conservative allowance is usually made in building lines in sleet districts. In general, lines in the sleet territories should not use a wire smaller than No. 4 B. & S.

Power arcs are frequently started by lightning discharges and result in burning and breaking of the transmission cables, whereupon the towers are subjected to unbalanced stresses which sometimes cause their failure. The lightning arresters which are suitable for the protection of station apparatus do not, however, protect the lines themselves. This latter problem requires special consideration, such as the use of ground wires, arcing rings, etc.

The wire clamps which have been a source of much trouble and concern, with many breaks in the conductors, have lately received an amount of attention which is making their design much more satisfactory and promises to remove them altogether as a source of trouble.

Devices have been developed for locating faults in transmission lines, such as defective insulators. They must work.

however, under line potential, but give very close indications of the trouble even at distances up to 150 miles.

In this connection it may also be of interest to mention a device used by one large distributing company for detecting insulators. Wooden poles and pin-type insulators are used; the three pins of each circuit being grounded at each pole. A simple device is connected in this ground wire a few feet from the ground and this device will indicate to the patrol man whether the insulators have been grounded or not.

Arrangements are almost always made with residents near the lines for reporting troubles. It seems to be the general belief that rewards should not be offered for such services as a general rule. While this might be an eminently proper thing to do with some people, to whom from $2.00 to $5.00 may be of great value, with others in different circumstances it would be just the wrong thing to do. In any case such services should be acknowledged by a letter of thanks.

THE CHAIRMAN: Prof. Creighton's paper and Mr. Rushmore's report are now open for discussion.

DISCUSSION

MR. D. W. ROPER, Chicago: I would like to say one or two things about the local effect of lightning, and on the fact that in order to secure the protection of transformers, the arrester should be on the same pole with the transformer. We have all probably had frequent cases of transformers burning out with a lightning arrester one or two spans only away. Recently, however, in the city, we had a somewhat more startling case of that kind.

We have in the southeastern part of the city a 20,000-volt, 25-cycle line, which extends for, say, two miles from the substation underground, and then as an overhead line some six or eight miles further. At the point where the overhead line joins the underground line, we have an aluminum cell lightning arrester, with a discharge recorder. On a recent morning the arrester was charged in the usual manner, and the charge plainly shows on the discharge recorder. That same evening lightning struck the line about 1000 feet away from the arrester. The pole was somewhat scarred although not very badly shattered, but the

lightning burned off all three wires of the line, so it must have been a fairly sharp discharge. The lightning discharge recorder, however, failed to show any sign whatever of a discharge through the lightning arrester; so that we have here a case of lightning which will jump across wires three feet apart, and the effect of the lightning is so local that it fails to show at all on an arrester only 1000 feet away. I think that is one of the most startling cases of the local effect of lightning that I have noticed.

MR. F. B. H. PAINE, Buffalo: Speaking to Mr. Rushmore's report, it, as well as a good many other papers which have been presented here, refers to the use of steam auxiliaries for one purpose and another, and I think it well to call attention to the desirability of hydro-electric plants for auxiliary service. I believe that in the progress of our study for the economical production of current, we shall find more and more situations where water power may very properly be used for the peak load rather than for the base load.

In using water power where water is limited, where reservoir capacity may be present, but for a limited amount, very cheap hydraulic installations can often be made, which will carry the top load in the most economical way possible. When we realize that in a system having a load-factor of only about 50 per cent, the upper 10 per cent has only 100 hours use a year, and the upper 25 or 30 per cent has probably somewhere about 10 per cent or not to exceed 80 hours a week, it should be appreciated that any plant where labor is reduced for that extra amount and the investment is kept low, forms the cheapest possible supply for the top load.

I have recently become familiar with several such propositions where the hydraulic development, including the transmission lines necessary for its use, can be installed for about $70 a kilowatt. The operating expenses are practically *nil,* being simply fixed charges, and 10 per cent will cover everything. That is where the water is relatively limited. Those are typical cases of the use of hydraulic plant as an auxiliary for peak load purposes.

MR. ERIC A. LOF, Schenectady: This report really contains so much good material that it is hard to know what part to discuss. One of the most interesting parts of it, undoubtedly, is that relating to the operation of the high-voltage system. Con-

siderable trouble has, in the past, been experienced by the breaking down of transformers caused by high-tension switching. Every endeavor is now made, therefore, to cut out all this high-tension switching, and confine it to the low-tension side, both in the generator and in the substations. In many cases it is almost impossible to do this, because if you are to have an uninterrupted service, you must have selective action. In most cases, however, if you are careful in laying out the system, this can be accomplished just as readily if you make your low-tension switches automatic.

It is preferable to parallel all generators on a low-tension bus, and one transformer group should, if possible, be installed with each outgoing line, making the transformer and line one unit, the switch on the high-tension line being non-automatic.

The low-tension bus should be sectionalized so as to reduce the disastrous effects of a short circuit. It is common practise now to limit the capacity of each section to something like 50,000 kilowatts. That is the maximum capacity that any circuit breaker can safely rupture.

THE CHAIRMAN: I will now ask Prof. Creighton to close the discussion on his paper.

PROF. CREIGHTON: I would like to say a word about Mr. Rushmore's report, bringing out an important point in reference to protection. We are all familiar with the troubles due to high potential, especially from lightning, and we are all familiar with the troubles accompanying short circuits, but there have been comparatively few records made of high frequencies in which there was no high potential involved.

The methods of investigation on this subject have been made easy by Alexanderson's alternator. Mr. Alexanderson has built an alternator which will give a frequency up to 200,000 cycles per second. By applying a variable frequency to transformer coils it has been possible to pick out the resonant frequency for each coil or each group of coils. For example, with three coils in a series the application of 180,000 cycles, 110 volts at the terminal of three coils produces about 6000 volts on the inner coil. In that case the natural location of the arrester would be at the position of 100 volts at the terminal. Damage was done internally to the middle coil but the damage was due to the frequency, not to the potential. In résumé three factors are to be taken

into account, viz., high potentials, high currents and high frequencies. The high frequencies may be independent of dangerously high potentials.

In the matter of grounds, I agree entirely with the plan that connection should be made to the water pipe mains. The emphasis I want to lay on the subject at the present time is as between the use of pipe grounds and buried plates. In other words, the buried plates are no better than pipe grounds, and they cost a great deal more. It is entirely a matter of relative area exposed to the earth, and a certain degree of moisture in contact with that area.

The experience that Mr. Roper cited of a concentration of lightning is one of the most definite and accurate that has come to my attention. It is not a question of protective value of the arrester in this case, but simply a matter of having enough potential at the arrester to jump a gap that was set only 25 per cent above the line potential. In relative dimensions we have the fact that the lightning jumped about three feet between wires and yet 1000 feet away from that point it was impossible to get enough potential to jump a quarter of an inch. If the potential had jumped across the gap of a quarter of an inch it would have been registered on the recorder.

Mr. Rushmore: These coming big power transmission systems are going to be high-voltage distributing systems, and right here around Chicago, the State of Illinois is very likely to be covered in the near future with a high-voltage distribution system of something over 100,000 volts, distributing over long and complicated systems. This will call for the very rapid development of new apparatus and it is in the development of this apparatus that the manufacturing companies appreciate so much the assistance which they get from the operators, because it is only through such joint work, through such very hearty co-operation, that satisfactory apparatus is to be had.

The Chairman: We will now take up the next paper, which is entitled, "Factors Producing Reliability in the Suspension Insulator," by Mr. A. O. Austin, of the Ohio Brass Company, New York City.

FACTORS PRODUCING RELIABILITY IN THE SUSPENSION INSULATOR

The standard of reliability in most engineering work is based on the factor of safety provided to meet operating conditions. Where the hazard is great, due to uncertainty of conditions or lack of uniformity in material, it is customary to increase the factor of safety accordingly. In view of this and the very uncertain operating conditions imposed on the insulators, together with the physical properties of the dielectric, one would be led to expect a large factor of safety in the insulator. Investigation, however, shows quite the contrary to be the case, for so low are the factors of safety that a small increase will make considerable difference in the performance. This, together with the enormous investments depending on the transmission line, gives even a small increase in reliability high commercial value.

This is most apparent in the case of dielectric strength where an increase of 30 per cent would warrant doubling the cost, if by so doing it could be accomplished. While this at first may seem unreasonable, the factors of safety are so low that the reliability of the insulator is somewhat similar to that of a steel spring working near its elastic limit on a fluctuating load. In the case of the spring a change in the amplitude of vibration, causing a change in the maximum stresses, by even a very small per cent makes a great difference in the life or reliability.

In the insulator as in the spring, the maximum stresses set up will have much to do with determining the life or reliability. Carrying the comparison still further, surges with steep wave front may start initial breakdown in the dielectric, the performance being similar to the spring worked to a point where the elastic limit is exceeded or crystallization takes place very rapidly. Under these conditions the life is necessarily very short if the severe conditions are maintained. The spring is effected by the temper, and if too soft a load which could be carried for a long time by a hard spring will cause rapid destruction. Just as we would expect a difference in the performance of hard and soft steel, so should we expect a difference in porcelains where the composition may vary widely, to affect the maximum electrostatic flux necessary to start appreciable damage.

Since the mechanical requirements are quite definite and their solution affects the electrical factors of safety, it is well to consider these first. Being free from bending moments the tension insulator has many advantages over pin or pedestal type insulators for mechanical loads. This was appreciated a long time ago, for if we go back 12 or 15 years when the insulators and pins were mechanically weak, we find many pieces of tension construction similar to that of the present day, a few fine examples of which are still in operation.

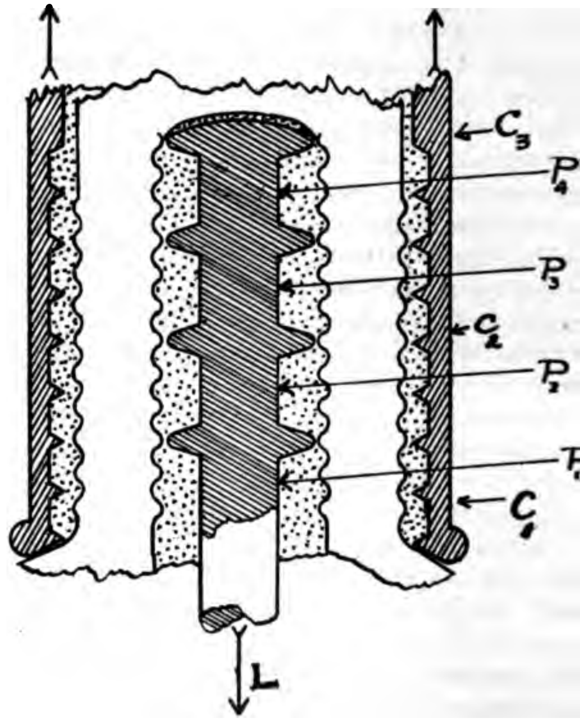

FIG. 1

When the insulator is light or the span short the internal mechanical stresses of the insulator may usually be neglected with safety. The present tendency, however, toward long spans and large sizes of conductor produces high working loads setting up stresses which, combined with internal stresses, may so lower the factor of safety that destruction of the dielectric is only a matter of time.

For the porcelain insulator it is necessary to consider the stresses set up by the working loads, those due to difference in the coefficients of expansion of porcelain and metal and the stresses set up by the cement or oxidation of the metal. For glass we have in addition the very uncertain internal stresses due to uneven shrinkage in cooling.

A brief analysis of the stresses in Fig. 1 will show that these are of importance and should be considered in the mechanics of the transmission line.

For Fig. 1 the following notation will be used:

A_i = 1.78 sq. in. cross sectional area iron or metal

A_p = 2.9 " " " " " porcelain

E_i = 20,000,000 modulus of elasticity for iron

E_p = 2,500,000 " " " " porcelain

λ_i = .00001175 temp. coef. of linear expansion for 1 deg. c. for iron

λ_p = .00000585 temp. coef. of linear expansion for 1 deg. c. for porcelain

L = elongation in unit length of porcelain due to greater temp. coef. of steel.

The stress developed in the porcelain due to change in the temperature is equal and opposite to that in the steel, hence, the following equation:

$$A_p\ L\ E_p = [(\lambda_i - (\lambda_p + L)]\ A_i\ E_i \quad (1)$$

Simplifying we obtain:

$$L = (\lambda_i - \lambda_p) \left[\frac{A_i\ E_i}{A_p\ E_p + A_i\ E_i}\right] \quad (2)$$

or substituting values for Fig. 1, L = .0000046. (3)

The stress per unit area in the porcelain will be $L\ E_p$ = .0000046 × 2,500,000 = 11.5 lb. per sq. in. for 1 deg. c. or for a 40 deg. c. change in temperature from that of assembling gives an initial stress of 460 lb. per sq. in., which without any other load leaves a factor of safety of only 5.4. Fortunately stresses of this magnitude are seldom developed, but are such that on hot days damage caused at a previous time from static puncture, the stretching of pin under heavy loads in cold weather or mechanical flaws, may be shown up. If the surface resistance is too low on strain insulators, heat may be generated which would have the same effect.

Most commercial types depend on a shearing area of cement for their mechanical strength. As the shearing strength of cement may be 2000 lb. per sq. in., and the tensile and shearing strength of porcelain is only approximately 25 per cent higher, the possible stresses developed in the porcelain before failure of the cement must be provided for. This is no easy problem, for the best theoretical solutions must be modified to meet electrical requirements or those of cost.

The inspection of Fig. 1 shows that the maximum stress due to load is at section P_1 in the pin, while that in the cap is at C_1 or at the other end of the head, making the distribution of stress very uneven in the porcelain.

The method of treating the mechanical stresses in the head may be varied to meet these conditions, it being possible to estimate maximum stresses to a fine degree of accuracy in some types, while the problem is very difficult and the result uncertain in others. In the following example it is wished only to call attention to possible difference in real and apparent factors of safety and their possible effect on the reliability of the insulator, particularly where the stresses are high.

Where the area of metal in the cap is large compared with that of the pin, nearly all the stretch or deformation will take place in the pin, so for simplicity the stretch in the cap may be neglected in the following. There are many commercial designs in which no use is made of this stretch in the cap, in which cases the following solution comes very close to representing the conditions.

In Fig. 1 the shearing area is quite large compared with the pin, hence a high fiber stress with large resultant elongation may be produced. Since the elongation of the pin may be large owing to small area and comparatively great length, the stress will drop rapidly between successive sections of the pin as we go from P_1 to P_4. Up to the time the metal flanges begin to bend, comparatively little stress is carried in P_2 and still less in P_3, hence we may neglect that in P_3 without serious error.

If we let $A_p = 6$ sq. in. average arc of porcelain strut effected by compression load

$A_i = .306$ sq. in. area of metal pin at P_1 and P_2

$l_p =$ (1 in.) length of porcelain strut

$l_i =$ (.55 in.) length of section P_2

$T_2 =$ load carried by flange P_2

$T_1 =$ load carried by flange P_1,

in order to develop the stress T_2 the flange must be given a deflection X_2, or if we assume X_2 it follows that

$$X_2 = \frac{T_2\ I_p}{A_p\ E_p}$$

In applying T_2 section P_2 is elongated by an amount

$$T_2 = \left(\frac{I_i\ M_i}{A_i\ M_i}\right)$$

which must be added to X_2 or the deflection of the upper flange to obtain that of the lower X_1, hence,

$$X_1 = X_2 + T_2\left(\frac{I_i}{A_i\ M_i}\right)$$

Since the stress must be proportional to the distortion

$$\frac{T_1}{T_2} = \frac{X_1}{X_2}$$

Substituting for X_1 and X_2

$$\frac{T_i}{T_2} = \frac{X_2 + T_2\left(\frac{l_i}{A_i\ M_i}\right)}{X_2} = 1 + \frac{T_2\left(\frac{l_i}{A_i\ M_i}\right)}{T_2\left(\frac{l_p}{A_p\ M_p}\right)} = 1 + \left(\frac{l_i\ A_p\ M_p}{l_p\ A_i\ M_i}\right)$$

and applying values gives

$$\frac{T_1}{T_2} = 2.35$$

but the total load on the pin must be the sum of that carried by the flangers or

$$T_1 + T_2 = 3.35\ T_2 = L$$

or where L is the working load on the insulator the load carried by T_1 is

$$\frac{2.35}{3.35}\ L = .70\ L$$

Where the flange is stiff a very high stress is then set up in the porcelain adjacent to the lower flange. Test shows that owing to uneven distribution of stress, the average shear is approximately 1400 lb. per sq. in. for the given example. Using the value and an area of 2.75 sq. in. we find that a load L of 5500

lb. produces a shear of at least 2000 lb. per sq. in. in the porcelain or develops an ultimate shearing strength in the cement. Now if the flange distorts before this load is reached, the second flange carries more and a greater ultimate may be placed on the insulator. This method, however, is poor as high stresses may be set up at comparatively low loads.

Curve A, Fig. 2, shows the factor of safety for a given load based on the ultimate of the insulator, and curve B the true

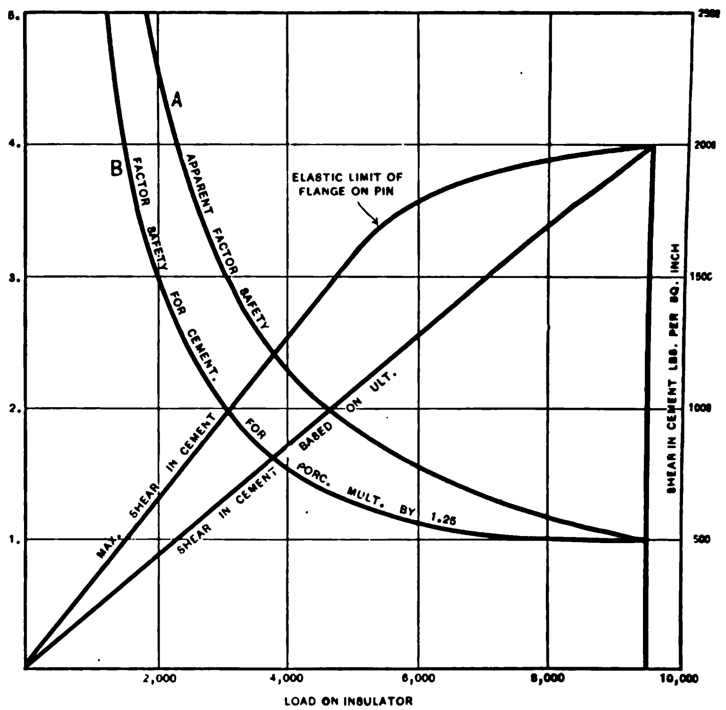

FIG. 2

factor of safety or that based on maximum stress set up in cement or porcelain, which shows that the factor of safety is cut down rather early.

These curves prove that it is important to use as few strains or dead insulators as possible, for where the conditions are severe a single insulator may be a greater hazard than many miles of purely suspension line.

Fig. 3

Fig. 4

Insulators of the better types have long been designed to meet abnormal conditions of surge rather than normal line voltage. To prove this we have only to consider the severe commercial tests and the comparatively low values obtained by close spacing. Details of design, about which more will be said later, also show this clearly.

The most severe conditions imposed on the insulator are the surges due to direct stroke of lightning. Fortunately, these surges although of enormous striking power, owing to steep wave front or extreme high frequency, are necessarily very much localized. The surges due to arcing grounds and switching while of much lower magnitude may affect practically the whole system, and the total damage may be far more than in the case of lightning. Lightning may cause an insulator to spill, doing little damage in itself, but the disturbance due to power arc and switching may be serious.

If the surge is of sufficient magnitude the insulator may fail by puncturing, flashing over the surface (Fig. 3), or through the air (Fig. 4). Failure by puncture means a shut-down, and arcing over the surface may be equally serious, due to damage from the power arc, while failure of the air means only momentary interruption at the utmost.

FACTORS GOVERNING PUNCTURE

In the suspension insulator or any other type, the probable failure of a part will depend upon its dielectric strength and the stress thrown upon it. The dielectric strength will depend on the specific dielectric strength of the dielectric and the geometric relations of the two surfaces. Prof. Harris J. Ryan gave much practical information on this subject over 10 years ago, which has proved invaluable in attempting to increase the dielectric strength of insulators.

Fig. 5 shows the effect of the geometrical relations in producing dielectric strength, based on the maximum stress set up. The high efficiency suspension insulator as originally designed had a dielectric strength of 135 kilovolts for a specific dielectric strength of 250 kilovolts per inch. At 90 kilovolts the maximum stress set up in the dielectric is $\frac{90}{135} \times 250$ kilovolts = 166.4

kilovolts per inch. This gives an average factor of safety of $\frac{250}{166.4} = 1.5$ for flashing voltage at normal frequency. Snap judgment says, increase this factor. This can be done at the expense of mechanical strength, increasing the section length or the diameter. The first method may be applied where the stresses

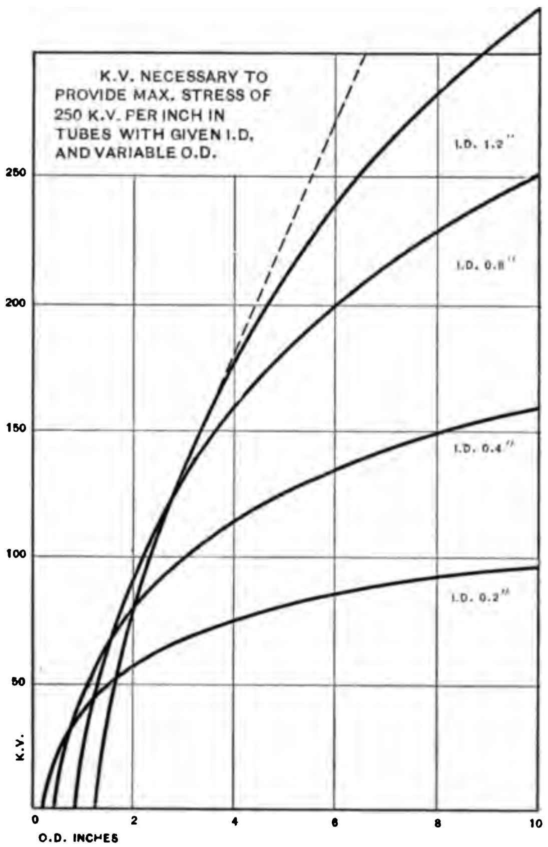

FIG. 5

are light; the second, however, not only increases the cost but causes the unit to carry more stress in the string, defeating its object. The third method means greatly increased cost and is questionable from an engineering point. Limiting the stress on the unit produces practically the same result at less cost.

The effect of testing is to raise the average dielectric streng
and is effective in proportion as it accomplishes this result. ˙
anyone familiar with testing it is apparent that there is a mark
difference in testing at just below flash-over and where the pa
are spilling. In the latter instance, surges are set up depending

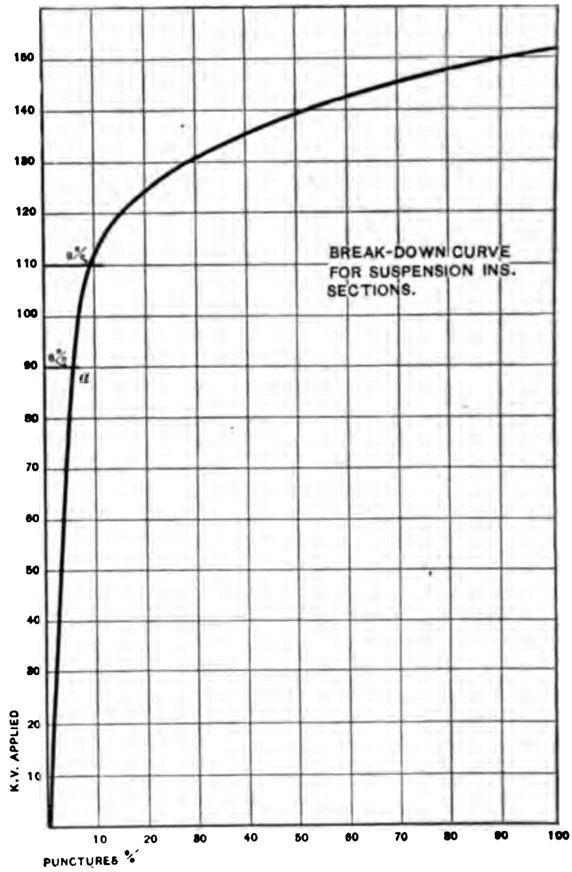

FIG. 6

the constants of the apparatus, and much more effective weedi
out is obtained.

Fig. 6 shows a puncture curve for suspension discs. Negle
ing the time effect it is apparent that if we raise the voltage up
6 per cent puncture, the minimum dielectric strength will be 90 ki

volts, which is flash-over voltage of the disc at normal frequency. This test is applied to unassembled ware and is practically the limit for testing in quantity. If in place of stopping at (a) the voltage is raised until 9 per cent have been weeded out, the minimum dielectric strength will be raised to 110 kilovolts. It was found that this could be done commercially by one of two methods, the following being in commercial use since September, 1909, and known as the momentary flash-over or kick test. Owing to the recent prominence given to high-frequency tests a few words about this test may be of interest.

Fig. 7 shows in diagrammatic arrangement, the capacity of the conductor as ordinarily used for the condenser. The series gap cuts out the lower part of the wave, and when it jumps it

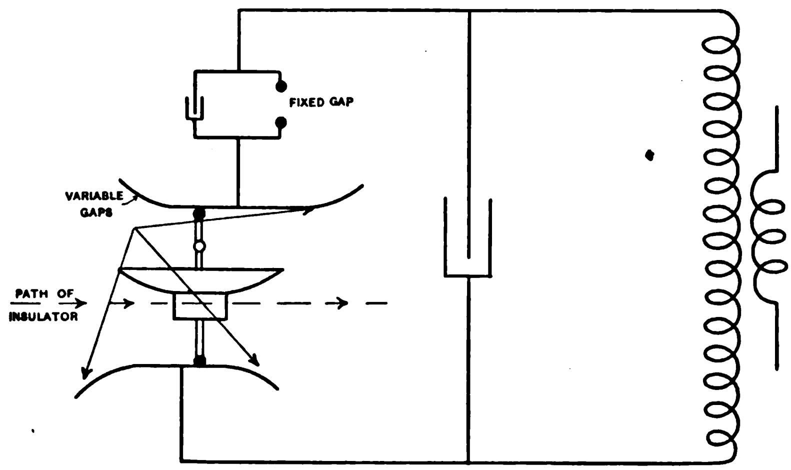

FIG. 7

shunts itself, throwing a sudden stress on the insulator much higher than could be applied ordinarily, owing to the time lag for the break down of the air and the absence of shunting corona around the insulator. Surges are also set up where the gap and insulator spill, the equivalent kilovolt of test being taken from the curve.

Fig. 8 gives evidence of the severeness of this test, showing puncturing near the edge in material which had previously been tested for 10 minutes at flash-over voltage.

For the effect of time on the failure of the insulator see an article on the "High Efficiency Insulator," Proceedings of the A. I. E. E., June, 1911.

We have many examples in practise showing that the time lag in protective apparatus or air-gaps permits of a piling up of stress much greater than that at normal frequency. The abnormal piling up of voltage will depend upon the steepness of the wave in front and the energy back of the surge. Where there are large

Fig. 8

amounts of energy, there may be multiple relief paths, the one which fails first not being always the one which takes up the destructive discharge. This is important in analyzing cases of failure and in considering protective apparatus. The abnormal

reactive drops in potentials makes it necessary to provide for surges in the immediate vicinity or preferably in each insulator.

TIME LAG IN PUNCTURING

We have many examples in operation that show conclusively that we gain in reliability as the factor of safety (based on dielectric strength to flashing distance) is increased. The effective protection of comparatively weak multipart pin insulators under severest conditions shows that dangerous stresses on the parts may be kept down by limiting the air distance around the whole insulator.

THE EFFECT OF SPACING OR SECTION LENGTH IN INCREASING THE FACTOR OF SAFETY FOR THE SECTION

Since the comparatively small factors of safety in a unit or section could not possibly produce a high enough degree of reliability to withstand the piling up of stress under surge, it is necessary to increase this factor of safety by adding more units. It is apparent that nothing will be gained for flash-over stresses if the flash-over of the string is n times that of a section.

If the section length is too long for the flash-over the section having maximum stress spills, and the insulator fails by cascade action, as in Fig. 3. If, however, the design is such that the flash-over of the unit is comparatively high compared with its length, the protecting air path around the complete insulator breaks down before we reach flash-over in the unit, as in Fig. 4. If we take an insulator of this type (one having a free arcing characteristic) and still further shorten the section length, the flashing voltage will be less for the entire insulator and the maximum stress on any unit reduced by approximately the same amount, or, we may safely say, the factor of safety is increased by bunching.

Insulators which are similar but with different section lengths have approximately the same relative stress distribution for the same number of units in the series. Hence the following method is of unquestioned value in comparing factors of safety.

The tested factor of safety is found by dividing the product obtained by multiplying the total tested strength of the units in the string by the flash-over of the string; when N = number of sections in string, T = flash-over of section, A = arcing voltage for string. Then the factor of safety gained by placing the sec-

tions in series will be $\frac{N\,T}{A} = C_f$ or the average factor of safe[ty]
for sections in string.

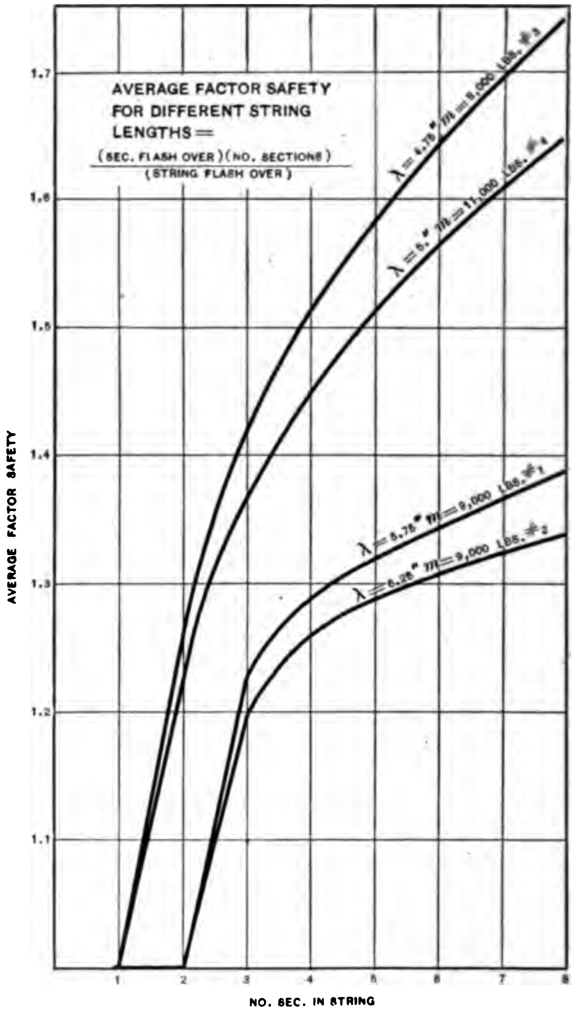

FIG. 9

It was seen that the tested factor of safety for the secti[ons]
could be raised by the surge test to $\frac{110}{90} = 1.22$. Then in or[der]
to get the average tested factors of safety, the values in Fig[. 9]
should be multiplied by this quantity to obtain C_f.

Fig. 9 shows the comparison of four different high-efficiency insulators, three of which have been in operation for some time. While these curves show the general tendency of an increase in the factor of safety with an increase in the number of units, poorer stress distribution for surge in the long string partly offsets this.

The tendency of the factor of safety to increase with the number of units is important, as shown by the curve in Fig. 9. Unfortunately the term "string efficiency" is sometimes applied to the reciprocal of C_f. This is very misleading, for a poorly designed insulator failing by cascade action, and a dielectrically strong insulator, may have the same values for efficiency on this basis.

Stringing the insulators out to give high flash-over values for a given number of units has misleading commercial advantages, for the resulting insulator is deficient in dielectric strength.

DISTRIBUTION OF STRESS IN THE SERIES

The stress varies throughout the series and by making use of the position of the conductor, the distribution of stress can be greatly improved for the end sections. Only too often is this overlooked with resulting increased damage to the lower section by overstress or power arc.

Fig. 10 shows an effective means of producing stress distribution by using horns to control the electrostatic flux in the series. The shape and number of horns may be changed giving practically any gradient, which with short striking distances gives high factors of safety.

A device of this kind is much better than condenser plates at top or bottom of the string or at the units, for the clearance to the tower need not be cut down and the insulator is open for inspection and clearing of the rain. It must also be remembered that a good stress distribution at normal frequency may not hold under the severest surges, and an increased capacity of the string behind the unit may only permit the surge to strike a harder blow. Not only can the gradient be controlled by the shape and number of horns, but protecting air paths may be provided for any unit or the whole string, as shown in Fig. 10.

Porcelain, like air, will withstand an enormous stress applied for an extremely short time. If, then, the time lag of the protecting air path can be shortened, added protection will be acquired. Fig. 11 shows one method of doing this and Fig. 12 another.

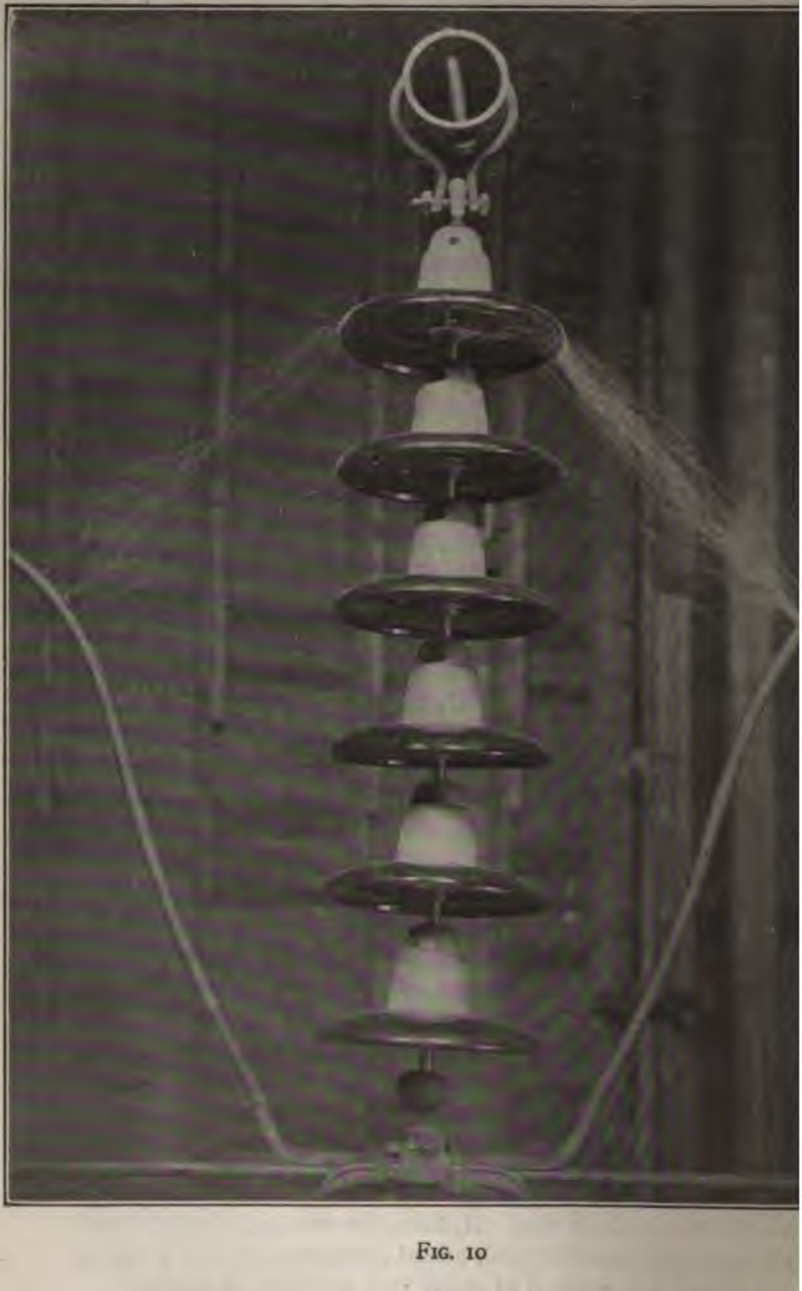

Fig. 10

The discharge points concentrate the electrostatic field and rten the distance, which must necessarily cut down the time l determine the path of arc. The points are so formed and ated that initial ionization is produced at normal voltage, tially breaking down the air path and reducing the time for ef, for part of the surges at least. Except in unusual cases arc will be prevented from running out on the conductor. It

FIG. 11

l be noticed that the insulators have a sharp-edged flange near lower end of the cap. This flange reduces the maximum flux the lower end of the cap for the severest surges. It is made

rather sharp so as to concentrate the flux at its edge. Th does effectively on the top unit but with no effect on the ir mediate ones.

These discharge horns are in effect a safety valve wi short time lag. They were first installed under unusually se conditions in Mexico and have since been used on a numbe large installations in this country.

The air-gap as a means of protection is very old and tried out, being simple and efficient. It is well to note in connection that the best types of insulators have short prote

Fig. 12

paths in proportion to their flashing voltages. Few realize far this has been carried in commercial types. Fig. 13 sh this up well, and the table following it shows that if there is thing in a protecting air path, the small insulator could w stand a surge that would destroy the larger and still have so thing to spare.

The low flash-over of the large insulators is caused by shunting corona which of course does not have time to build up and lower the flash-over for protection, for a surge of steep wave front. The absence of corona or surface stress on the small efficient types tends to make their flash-over less dependent on frequency. This is important, as it tends to prevent interruption

FIG. 13

from spill-overs due to surge of increased frequency but moderate rise, and tends to maintain the free arcing characteristic of the insulator.

While the type of insulator has not changed materially, it is well to note that insulators are being installed on 110 kilovolt lines to-day having an average factor of safety for the unit in

the string of over 1.7 as against 1.3 and 1.38 less than two years ago. The multiple insulator, Fig. 12, used for heavy suspension and dead ends has a factor of safety on the same basis of 2.37.

It is only natural that insulators should be purchased on a weight and size basis, and at first it was necessary to raise the rating at the expense of factors of safety in order to commercialize the small efficient types. In the future, the demand for greater reliability in order to protect the large investments dependent on the transmission line will make it possible to fully commercialize effective factors of safety with resultant improvement in the insulator. It must be borne in mind that the reliability of the insulator depends not only on its inherent properties but also upon the imposed conditions, the mechanics of the line being, therefore, very important.

TABLE SHOWING A COMPARISON OF THE DIFFERENT INSULATORS

(Illustrated)

Figures	Flash-over in kilovolts for section	Flash-overin kilovolts for string	Factor of safety in string. T
3	67	400	1.
4	90	388	1.63
10	67	233	1.73
11	90	375	1.68
12	90	310	2.33

	Small Insulator	Large Insulator
Arced	80 kilovolts	75 kilovolts
Surface distance	8¼ in.	19¼ in.
Shortest striking distance	6¾ in.	14 in.
Weight	4 lb.	8¼ lb.

DISCUSSION

PROF. CREIGHTON: I am glad to know that Mr. Austin has made tests with high frequency. The first problem with insulators is no doubt in the manufacture, to keep out faults in the actual firing. There is also the factor of dimensions that comes in. After these points have been passed, however, the interest in the insulator is the same with all of us; that is, will it stand up. It is a rather significant thing that insulators have been tested for months on 60 cycles and they have never been strained on 60 cycles or generator frequency. The only strain that comes

on an insulator is high frequency. High frequency has an effect on the sparking of the insulator entirely different from low frequency. If we get an insulator with three skirts and subject it to a 60-cycle strain, the arc will usually go around the upper skirt and jump to the pin. If the frequency is gradually increased, that surface spark which runs over the top skirt will gradually creep under each one of the other skirts, until when you arrive at a frequency of about 100,000 cycles per second, instead of having a flash from the upper terminal to the pin, the circuit will follow every one of the surfaces, and even run up and down the main petticoat. By going high enough in frequency the circuit will follow even the little petticoats. The high frequency runs over the entire surface and in that way finds any imperfection in the porcelain. I should like to have Mr. Austin's opinion on a proper high-frequency test, whether it should be a sudden disrupted discharge or a discharge by an oscillating circuit.

Mr. L. C. Nicholson, Buffalo: Mr. Chairman, in regard to Mr. Austin's paper, I read it carefully enough to get the meat out of it, and I gather that the factor of safety which he has tried for is obtained by placing discs as close together as may be, so as to cause as much thickness of porcelain to come between the electrodes as possible for a given spacing between electrodes. In other words it practically refers to the connection between the dielectric and flash-overs between the terminals. That may be arranged in two ways, by placing the discs close together, and using a large number of them, or placing them a normal distance apart and using auxiliary electrodes, which would decrease the flash bolts.

Some years ago I advocated before the American Institute of Electrical Engineers one of those methods of increasing the factor of safety, by reducing the flash-over distance and by causing the flash-over path to be a straight line instead of an indirect curve around the edges. I am glad to see that Mr. Austin inclines to the same opinion.

In the last part of the paper considerable is said about the effect of mechanical stress on the electrical value of insulators, although I can not say whether he follows that to a conclusion or not. It so happens that in the last few weeks I have had in charge considerable work in the way of simultaneous

and separate mechanical and electrical tests on suspension insulators, in order to find out if the insulator is as strong electrically under simultaneous mechanical pull as it is when tested fully without loads, and furthermore to find out what causes the difference, if any exists. I have not been able to draw these tests to a conclusion as yet, but in a general way I find that insulators made for a minimum of 8000 pounds mechanically will begin to puncture at 5000 pounds and flash over on 25 cycles. At first they have a dry flash-over at 5000 pounds load. A very marked loss will occur at 6000 pounds load, and they will all be down, of course, before they fail mechanically.

To see whether or not the combined stresses, mechanical and electrical, cause the premature puncturing of an insulator, I carried out some tests in which the insulators were first subjected to a mechanical load of 5000 pounds, and then, with the load off, tested to a dry flash-over; and then again with 6000 pounds and on up. I found exactly the same percentage of failure, that is within the limits of the test, as during a mechanical strain. That seems to indicate that the effect was purely mechanical, and was not a combination of electrical stress and mechanical stress.

However, there is one particular point about that which may seem to indicate the contrary. Immediately upon the application of the dry flash-over, a disc that passed a test of 5000 pounds later on was tested with a flash-over at 6000 pounds, and then tested with a flash-over in 5, 10 and 15 seconds, and it would puncture. If the porcelain had been ruptured you would naturally suppose that it would not have held the voltage at all. Putting those things together, molecular strain is indicated, and the subject needs considerable study.

Mr. Austin: Regarding the severity of tests placed on insulators, it is sometimes a difficult matter to decide whether a test is too severe, and the reliability of the insulator will be lowered instead of increased by overtesting. In general, the ratio of dielectric strength to flash-over voltage is high enough to permit the material being tested to flash-over voltage. The best material has a well-defined knee in the dielectric curve (see Fig. 6), and voltages below the knee of the curve weed out faults, while voltages above may destroy good material. Faults and internal stress in the insulator tend, in time, to cause failure, and,

as high electrical testing tends to eliminate this material, it is important that the tests be as high as is consistent with the dielectric curve.

High mechanical testing tends to break down the molecular structure, and this may show up, in time, under the stresses produced by load and the expansion due to fluctuating temperatures. While lack of vitrification permits the passage of destructive current at comparatively low voltages, it has little effect on mechanical strength. Mechanical tests tend to open up defects, and, as a removal of the load may tend to close them, it has been customary, on certain large types, to test under combined mechanical and electrical stress. Care should be taken that the mechanical loads are not too high, otherwise the insulators will be poorer after test than before.

A high mechanical load will lower the dielectric strength of some insulators over 50 per cent, while no appreciable effect can be seen on other types. Oscillatory discharges, setting up high maximum stresses, tend to affect insulators under mechanical stress much more than under electrical stress at normal frequency. This, as well as the effect of time, should be given careful consideration in making combined tests, particularly if the voltage is at, or above, the knee of the curve. This may easily occur, due to lack of vitrification, or material of low specific dielectric strength.

THE CHAIRMAN: When the program of the Hydro-Electric and Transmission Section was being made up, we all felt that a description of our newest and largest hydraulic plant would be of great interest. In the building of such a plant as that, some one man and his efforts usually stand out very prominently. We were extremely fortunate in our search for the right man to describe this plant, and I know you will all enjoy with me hearing Mr. Hugh L. Cooper on The System of the Mississippi River Power Co.

MR. HUGH L. COOPER, Keokuk, Iowa: Gentlemen of the Association: When I received my invitation to come here I wondered why I was invited to a place where men were supposed to be discussing electricity and practically that only. I have promised the Chairman that my remarks shall be cut down to the irreducible minimum, as the pictures are much more interest-

ing than anything I could say, but before I show them, I want to tell you a short story while my knees are synchronizing (laughter).

When a hydraulic engineer starts to speak on an occasion of this kind, and gets to talking about so many thousand or hundred thousand yards of concrete, and so many million cubic feet of water, and what-not, he is very likely to be accused of bragging. There is no trait of human character that I think more despicable than bragging about what one has done or is going to do, and if I ever had any tendency to brag, I got it all cured in one day on a ship. It occurred in this way. I was crossing the Atlantic, and one day, while sitting on the back stoop of one of the decks of the ship, a fellow came along with a nice appearance and great deal of moustache, and called me Colonel. I never knew why he called me Colonel, but two or three times lately I have been telling this story to people intimately acquainted with me, who suggested it might be because I was nutty. He said he had a scheme, and that this scheme was one that he wanted to present to me with a great deal of seriousness as it grew out of his discovery that the ship we were on was about out of coal. We had been out about sixteen days, and those of you who have been over on the five-day boats know what that means. We were all very much digusted, and this gentleman, who said he was from Alabama, proposed to me to build a coal island out in the Atlantic ocean somewhere. He was going to raise the money, and after the island was built he was to stock it with coal and sell it to these slow ships. He thought there would be a great deal of money in it.

In view of the fact that it was so much in evidence that we needed coal, I agreed to take the question up seriously. Fortunately, I got to the Captain first and told him about the proposition, and he said it was a fine idea, as there had been many occasions when he needed that island. So we had a conference, and the program outlined was that the Colonel—no, the General —he was from Alabama—was to raise money enough. I was to build the island, and we were to use our boat, which we did not think much of as a passenger steamer, to build the island with. I thought we could cut some holes in the bottom of it, drop stone into it, and eventually create the island. In order to give

some dignity to the investigation, I disappeared into my stateroom for two or three days, and I don't know how many decimal points I may have added or subtracted; but, anyhow, the best that I could make out of the project was that to build the island where the captain wanted it—and he told us it was only two miles deep there, by the way—would take about 565,000 years; and not counting any commission to the General, not allowing any engineering fees whatever for me, and not having an incidental column at all, it would take about eleven times as much money as there is supposed to be in all the world. I reluctantly let go of that commission right there. That island was to be only a thousand feet square on top; it was to stick up out of the water only a hundred feet, and I have always thought that if it would take a human being any such term of years to build a little thing like that, what we really succeed in doing is not worth bragging about.

Now, I want to take you over some of the earlier forms of power, not all electric power either.

[The address of Mr. Cooper here became a description of the construction of the water-power plant at Keokuk by means of a large number of stereopticon pictures, each of which was explained in detail and became the basis of running comment by the speaker. The following is a condensed report of this address, which it is impossible to transfer to the printed page in full.]

THE SYSTEM OF THE MISSISSIPPI RIVER POWER COMPANY

Probably the first water-power used by man was the monjoli. A bowl or stone or other matter was placed in the earth to receive the corn which was to be ground as in a mortar. On one end of a horizontal log was fitted a piece of hard wood, which became a pestle to batter the corn as the end of the log carried it up and down. On the opposite end of the beam, which was pivoted near the middle, was a log hollowed out in the form of a trough into which water ran from a spring. As the trough was filled with water it became heavy enough to sink by gravity and raise the opposite end of the log carrying the pestle, while as soon as it reached its lowest position, the water ran out of the trough upon the ground, when the pestle end at once fell by its own weight, striking the corn in the crude mortar and crushing it. These blows were delivered with varying frequency, but in the course of time sufficient corn was converted into meal to supply the needs of a family. I was fortunate enough to see this pioneer water-power apparatus in actual use by the people in the mountains of Brazil. It was introduced into that country in the early part of the sixteenth century by the Portuguese, and in the country districts there nearly every farmer has an apparatus of this kind, and uses it in preparing sustenance for his family. There is a Portuguese historical statement which is more or less a myth, that the monjoli was brought into Western Europe from Asia, with the inference that it was invented by the Chinese, but there is no real evidence to support this, except the general principle that almost everything worth while in our modern civilization has come originally from the land of chop-sticks and pigtails.

It is a far cry from this crude mechanism to the complex curves of the modern turbine. The evolution of the water wheel includes the labors of many men of several different countries during many years. The first water wheels were impulse wheels of the type familiar to our grandfathers, and it was considered a great improvement when the undershot wheel was replaced by the overshot wheel, which had an increased efficiency over its immediate predecessor. Finally, the idea of utilizing the back pressure

of the water was applied to waterwheels, and since then has been made very familiar to high school students in the form of a glass tube bent into the shape of the letter S, and pivoted in the middle, which revolves in the laboratory when water is forced to flow through the tube. There is, in Paris, a wooden model of a reaction wheel, which seems to have been made some time before the year 1700, and Poncelet advocated the principles now used in the reaction turbine as early as 1826. American design of reaction wheels had its first achievement at Lowell, in 1846, when Uriah Borden reached 78 per cent efficiency in his design, but it was James B. Francis, who flourished about the middle of the last century, to whom we owe sufficient to entitle him to be called the father of the modern turbine. His method of causing water to flow from the rim of the wheel towards its hub is now generally called the Francis type of wheel in both Europe and America, and whatever changes are made in the details of design, most of the successful waterwheels of to-day are of the Francis type. It is only within the last decade, however, that the Francis turbine has been developed into a success upon which absolute dependence can be placed at all times. The new turbines used in the water-power development in the Mississippi River are all new designs of the Francis type and have shown at the Holyoke testing station an efficiency of about 88 per cent, which is gratifying to all concerned.

This water-power development extends from Keokuk, Iowa, across the Mississippi to Hamilton, Illinois. Its building comes at the end of a full half century of effort on the part of the people of that section to utilize the fall of the river at the Des Moines rapids. For many years the newspapers published countless articles, telling why this water-power should be utilized instead of being allowed to go to waste; a score of men appeared with projects for its development, ranging from the utterly foolish to the merely impossible. The people thereabouts kept eternally at it, apparently because they did not realize the impossible when they saw it. As a matter of fact, the Mississippi River at that point could not be dammed to develop water-power until engineering science had advanced past its capability of the last century, and until the modern revival of concrete had reached a stage where there was a large production of cement in America. But, when the time did arrive, it found the people still actively

at work and ready for the quick connection with engineering and capital which they formed at the earliest possible moment.

Even then the real difficulty was to get capital interested in the proposition. The first 38 financiers whom I approached with my well thought out story of what could be accomplished there in the Mississippi River, rebuffed me with as much chilliness and firmness as politeness. Finally, after years of labor, argument and persuasion, the capital to construct the work was obtained in England, Germany, France, Belgium, Canada, and a part of it only in the United States.

To still further convince me that it was not simply a job of making drawings and blue prints, and of installing concrete and steel there in the river, the United States Government, through the War Department, then proceeded to formulate the requirements which were made a condition precedent of the franchise act which Congress had passed in favor of a little corporation formed by the People of Keokuk and Hamilton, which really was a sort of Trustee, and for all practical purposes, the people incorporated.

I have nothing but the highest appreciation of and praise for the great courtesy which has been shown at all times by the War Department and the office of the Chief Engineer of the Army while they have been in very close contact with our work there in the Mississippi River. They have been as considerate as a loving father bringing up a child in the way he should go, and they have had very definite ideas about the manner in which the rights and benefits of navigation in the river should be conserved by our work and at our cost. Sometimes I have thought that they were demanding not only a pound of flesh, but also that it be broiled well done; but they always did these things pleasantly so that it was difficult to keep from thanking them when they added a few million dollars to the toll which the United States is taking because it allows us to exist there in the Mississippi.

Our work is done entirely by administration and with the use of a considerable quantity of machinery which reduces muscular work to the minimum. Considerable time was spent in preparing for the actual work of construction, and this was fully justified by the rapidity with which the work was done after we began building the structures. The construction plant included over

15 miles of standard gauge railroad track, 19 locomotives, about 150 cars, several million pounds of steel, tens of millions of feet of lumber used in making the cofferdam and wooden forms for concrete, concrete mixers, derrick cars, travelling cranes and steam shovels of large size. About a million dollars were spent for the construction plant.

The work was in two divisions; one building the dam across the river from the Illinois shore, and the other building the power-house, lock and dry dock near the Iowa shore. These two divisions working along together in perfect co-ordination with the chief engineer greatly increased the speed of construction.

The first thing to do was to unwater the bed of the river where our structures were to stand. This was done by means of cofferdams. The cofferdam was made by building cribs of heavy cross timbers and filling the cribs with rock. The bottom of each crib was fitted exactly to the rock bottom of the river, then heavy timbers were placed to form a wall on the outer side of these cribs which were spaced 12 feet apart, and outside of the timbers was put a second wall of 2-inch planks. Finally clay was dumped outside of the crib and made an effectual seal against the water. An area of about 35 acres was enclosed in the cofferdam on the Keokuk side, which had for its western boundary the Iowa bank of the river. The cofferdam ahead of the main dam was built in practically the same way, in sections of several hundred feet; the work was so arranged that by the time the big concrete dam had advanced through one section, another section of the cofferdam was ready for it. The water was taken out of the cofferdam with centrifugal pumps, and so nearly watertight were they that seepage was entirely inconsequential. The concrete for the work was made out of the hard blue limestone there, and the stone provided by excavation from the bottom of the river to form the tail race was almost exactly what was needed for the concrete in the Iowa division. The rock for the Illinois division was obtained a few hundred feet away from the stone crusher. The sand was obtained a couple of miles down the river and pumped out of the river bottom by suction dredges which piled it ashore, the water running off. It was then lifted by clamshell buckets and a derrick, upon dump cars which were run in trains over railroad tracks to the concrete mixers. A stone crusher

to which the rock was hauled from the quarries broke it into pieces of proper size for the concrete and it was then conveyed by machinery to bins in the concrete mixing plant, where there were also bins for the sand. The sand, concrete and water were mixed in revolving drums and the concrete was poured into buckets, each holding a cubic yard and a half, setting on flat cars, so that a train was loaded in a short time and hauled to the place where the concrete was to be deposited. That for the dam itself was hauled over three tracks on top of a concrete portion of the structure.

Running upon a railroad track of 25-foot gauge on top of the dam was a travelling crane with a cantilever arm reaching 150 feet beyond the concrete end of the dam. It extended over steel forms, which were the moulds in which the spans of the dam were cast. In this way the dam was used to build itself. The dam consists of 119 arched spans, looking very much like a bridge, each span being an opening of 30 feet between the 6-foot piers. In each span between the piers is built a spillway, over which the water flows. Above each spillway is a steel gate sliding in a slot cut in a pilaster extension of the pier. The whole dam is set down several feet in the limestone bottom of the river to which it is attached as firmly as if it were an integral part of the bed rock. The structure is 52 feet high, 42 feet wide at the bottom and 29 feet wide at the top. The spillways are 32 feet high, vertical on the upstream side, and with an ogee curve on the downstream side. The steel gates extend from the top of the spillway a little above the point where the arches leave the piers. By opening and closing a various number of these gates the water level above the dam may be regulated. Expansion and contraction by heat and cold were taken care of by sheets of building paper on edge in different parts of the concrete mass; this need be done only near the surface of the concrete as the latter is not affected near the center of a large mass by changes in atmospheric temperature. There is an abutment at each end of the dam, and the total length is 4649 feet, or about 0.88 of a mile.

At the western end of the dam and almost at right angles to it is built the power-house, 1718 feet long and 132 feet, 6 inches wide. The substructure sets 25 feet down in the bottom of the river, and is a solid mass of concrete containing openings and cham-

bers through which the water flows to actuate the turbines. The superstructure houses the electrical installation of generators, transformers, oil switches and the like. The substructure, nearly a third of a mile long, half a city block wide, and 70 feet high, was cast in concrete by means of wooden forms, and while millions of feet of lumber were used in its construction, there was not a foot of wood in it when it was completed. A force of carpenters did some excellent joinery work in making the wooden forms, the sides of which next the concrete were perfectly smooth in order that the concrete surface might be so.

Spanning the width of the power-house were four travelling cranes, which also projected over the railroad tracks along one side of the structure. These cranes picked up the concrete buckets from the trains arriving from the mixer plant and deposited the concrete in the wooden forms. These cranes were moved along the power-house on a railroad track, the gauge of which was 125 feet; that is, the rails were that far apart.

In the substructure of the power-house are the 30 units of the water-power, each one consisting of a waterwheel connected with an electric generator and surrounded by the means by which the water passes through the wheel. Each of these 30 units is exactly like the other 29 and a description of one is a description of all of them.

In each case the water passes under an arch and into the entrance of four intakes guarded by a steel network which acts as a strainer. These intakes are over 7 feet wide and 22 feet high and each extends into the concrete mass, three of them finally joining together, and one running independently to the chamber in which the waterwheel is placed, which is technically called the scroll case. This chamber is 39 feet in diameter, is spiral in shape, and the curves of the intakes and slanting floors in both intakes and turbine chambers are carefully calculated so that the water is given a circular motion around the wheel and strikes every point upon the circumference with equal force, thus getting the greatest amount of power possible out of the water.

After passing through the wheel from circumference to center the water passes downward through a curve outlet, which at the top just below the wheel is circular in form and 18 ft. in diameter, and at its outlet in the tail race is oval in shape and of much larger size. The shape of this outlet, called a draft

tube, is such that it exerts a suction pull upon the turbine, so that this water wheel, in entire disregard to the lines of a famous poet, is actually run by the water which has passed. The water is discharged into the tail race excavated 25 feet deep in the bottom of the river. The power developed is that produced by the weight of the water passing through the wheel from a higher level above the dam to the lower level in the open river below.

The waterwheel is a casting of complex and carefully calculated curves, which, in this instance, presented problems that seemed almost insurmountable in the beginning. The conditions compelled a design of comparatively slow speed under a comparatively low head of water, and this involved very large dimensions. The larger number of waterwheels in use operate under a head of water several hundred feet high at very high speed and consequently may be made of comparatively small size. In consultation with several men especially skilled in the design of waterwheels we finally evolved a turbine for the Mississippi River development which is very satisfactory. It weighs between 65 and 70 tons, is over 16 feet in diameter, and over 11 feet high. It contains 21 vanes, called buckets, against which the water impinges, and through which it flows to make the wheel revolve.

The wheel is attached to the bottom of a steel shaft 25 inches in diameter, to the top of which is attached the revolving part of the electric generator on the power-house floor above. This shaft, carrying both the turbine at the bottom and the rotor of the generator at the top, revolves upon one bearing with a weight of 550,000 pounds. This bearing is lubricated by forcing oil into it under a pressure of 250 pounds to the square inch, and is so arranged that if, by any chance, this forced oil lubrication breaks down, the bearing settles automatically and instantly upon rollers immersed in oil.

This bearing is the top of a steel cone which rests upon the ring near the top of the turbine chamber, and this ring, connected to one side of the power-house floor by a steel drum, supports a total weight of nearly a million pounds. When it was tested with a weight of a million pounds the deflection was only a scant 0.001 of an inch, so firmly is it held in its concrete bed.

The revolving part of the electric generator is over 30 feet in diameter. The current is generated at 11,000 volts, and by

transformers is stepped up to 110,000 volts, at which it is transmitted over the line to St. Louis and intermediate stations.

The lock by which the boats pass the dam is located between the power-house and the Iowa shore, at the lower end of the work. It is built entirely at the cost of the Power Company and exactly as required by the War Department. It is 110 feet wide, which is the width of the Panama locks, is 400 feet long, and lifts and lowers steamboats through a distance of 40 feet.

Under the east wall of the lock is a tunnel 13 feet in diameter with lateral smaller tunnels 6 feet in diameter crossing under the lock floor like a gridiron. In each of these lateral culverts are seven openings. To fill the lock, the valves at the upper end of the large tunnel under the lock wall are opened and the water flows into it and through the cross culverts under the floor of the lock to come up into the lock through the 56 holes scattered all over its bottom so that there will be no eddies nor currents as the lock fills, and the steamboat is raised upon the surface of the water through the distance of 40 feet. When the lock is to be emptied the valves at the upper end of the tunnel under the wall are closed and similar valves at the lower end are opened, allowing the water to flow out of the lock in the reverse direction through the same channels into the open river below. The lower gates of the lock had to be designed to withstand the pressure of a wall of water over 40 feet high and at the same time to allow them to be opened and shut almost as easily as the doors of a building. These gates are of heavy steel frame work with a steel skin upon the inside of the lock. They weigh over a million pounds and have a tendency to sag which exerts a force of 374,000 pounds, even after a large quantity of weight is neutralized by their buoyancy chambers. In each gate is an air-tight cavity filled with air, which exerts some lifting force upon the mass of steel. The essential part of the hinge in each of these gates is a hemisphere of bronze resting upon the bottom of the river and capped by a hollow hemisphere of hardened steel which has been called the heel of the gate. These gates are operated by the same mechanism which is in use in the Panama locks, consisting of a steel bar attached to the gate at one end and to the wheel at the other end; as this wheel revolves the steel bar is thrust out to push the gate shut or is pulled back to pull the gate open.

Between the lock and the Iowa shore is a dry dock which the company is also building at its own cost according to plans and specifications furnished by the Government. This consists of a basin and a rather large area upon which will be built machine shops, office and other buildings.

The gate of the dry dock basin, the upper gate of the lock and the guard gate protecting the latter in emergency, are all three exactly alike, and, in fact, either gate may be used in any location if desired.

The upper lock gate is opened by sinking it under the water, so that the boat may pass over it; it is closed by raising it up out of the water as a barrier at the upper end of the lock. It is of steel truss construction, and its lower half is an air-tight chamber. When the gate is to be opened water is admitted into this chamber through a valve and the entire gate sinks exactly like a ship with her bilge cocks open. After the gate has sunk under the water and the boat has passed over into the river above, the turning of another compound valve admits compressed air to the air-tight chamber in the bottom part of the gate and opens an exit for the water contained therein. As the chamber in the gate is filled with air, the gate becomes buoyant and rises to the surface for exactly the same reason that an air-tight empty tin can will not stay under the water. This gate is provided with details of design and devices which make it fool-proof so that it may be operated by common labor without danger of its getting out of order. When repairs are needed upon it, it is merely slipped out of its place in its buoyant condition and towed around into the dry dock, where it may be repaired high and dry, and afterwards floated back to its place at the upper end of the lock.

The United States not only gets this lock and dry dock free of all expense, but has also installed at the expense of the power company an entirely separate individual power plant to operate them. This is placed in a short cross wall which connects the lower end of the power-house with the upper end of the lock. It consists of two small turbine wheels actuating two air pumps. These pumps furnish compressed air, which is carried in pipes to all the machinery in the lock and dry dock, for their operation, and furnishes perpetual power for the Government at practically no cost.

The pool above the dam is of such size, that the newspapers persist in calling it a lake. It is from 1 to 3 miles wide, and about 65 miles long. It furnishes deep water navigation for steamboats for over 60 miles up the Mississippi and over the Des Moines rapids which hitherto have been passed by a Government canal, 9 miles long, containing three locks. This canal cost the Government over $40,000 a year to operate, and is replaced by the new lock. Boats will be locked through in the new way in 10 or 12 minutes, and will save at least two hours' time between Keokuk and Montrose, the first landing above, as compared with the time required to pass through the old canal and its three locks.

The Mississippi formerly flowed several miles to the west of its present location, until a glacier came down from the northeast and dumped itself into the river a dozen miles above Keokuk. This glacial barrier forced the Mississippi to cut a new channel around the obstruction. This new channel is a few million years younger than the rest of the stretch of the Mississippi across the map of the United States, so that while the older river had cut its way into the continent with such a wide trough that the bluffs on either side are fully 10 to 20 miles apart, on this newer stretch which became the Des Moines rapids the bluffs are up close to the banks of the river. It was that glacier which made this water-power development possible, because otherwise so much land would have had to be overflowed above the dam as to make the cost of the development prohibitive. As it is, the company paid several million dollars for land which its dam overflows, and it is a matter of special gratification that 812 different farmers were settled with amicably, and to their entire satisfaction, while only six compelled litigation to determine the equity of their claims, and the awards made by the courts in all of these cases have been less than the company was willing to pay the land owner in the beginning.

In closing, I want to thank you very much for the patient attention you have given me to-day. If I have roused in your minds a little curiosity to see this job, you will find that it is so big we have not had a chance to build a fence around it; in fact, we are not going to build a fence around it. We shall always be glad to see you. The work is to be turned over soon to one of your members, the Stone & Webster Corporation, which is to manage the property, and I think I need not hesitate to say that

you will find them most agreeable hosts. I thank you very much.

MR. J. A. BRUNDIGE, New York City: Mr. Chairman, I move a vote of thanks to Mr. Cooper for his very interesting talk.

(The motion was seconded and carried by a rising vote.)

(Adjourned.)

THIRD HYDRO-ELECTRIC AND TRANSMISSION SESSION

FRIDAY MORNING, JUNE 6

THE CHAIRMAN, MR. HOLTON H. SCOTT: The meeting will please come to order.

The first number on the program is the Report of the Committee on Receiving Apparatus. Mr. M. R. Bump, Chairman, New York, is unable to be present, and the report will be read by Mr. W. N. Ryerson, Chairman of the Power Transmission Section.

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MR. J. A. BRUNDIGE, New York City: Mr. Chairman, I move a vote of thanks to Mr. Cooper for his very interesting talk.

(The motion was seconded and carried by a rising vote.)

(Adjourned.)

THIRD HYDRO-ELECTRIC AND TRANS-MISSION SESSION

Friday Morning, June 6

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The first number on the program is the Report of the Committee on Receiving Apparatus. Mr. M. R. Bump, Chairman, New York, is unable to be present, and the report will be read by Mr. W. N. Ryerson, Chairman of the Power Transmission Section.

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MR. J. A. BRUNDIGE, New York City: Mr. Chairman, I move a vote of thanks to Mr. Cooper for his very interesting talk.

(The motion was seconded and carried by a rising vote.)

(Adjourned.)

THIRD HYDRO-ELECTRIC AND TRANSMISSION SESSION

FRIDAY MORNING, JUNE 6

THE CHAIRMAN, MR. HOLTON H. SCOTT: The meeting will please come to order.

The first number on the program is the Report of the Committee on Receiving Apparatus. Mr. M. R. Bump, Chairman, New York, is unable to be present, and the report will be read by Mr. W. N. Ryerson, Chairman of the Power Transmission Section.

REPORT OF THE COMMITTEE ON RECEIVING APPARATUS

Your Committee has found that so little interest is taken by the members in this subject that it seems unwise to attempt to make any general report to this Convention. We feel that our subject is of the greatest importance, and that the solution of the problems advanced in last year's report offers more in the way of benefits leading toward the future stability and success of transmission work than any other solution before us. We do not think it possible to make a creditable report unless the Committee has at least nine months' time in which to prepare its data, and unless the members of this Association are willing to spend money in experimental work and special investigation. The success of the one company that has really taken up the problem of "holding the load" has been such as should arouse the wide-spread enthusiasm of our members. Before a full report can be made we must receive this enthusiasm and the help it will bring to us. We feel it imprudent to make any report other than that progress is being made, and we wish to impress on the Section the importance of having next year's committee appointed and at work not later than July 1.

Respectfully submitted,

Committee {
M. R. BUMP, *Chairman*
L. C. NICHOLSON
E. A. WEST
E. S. COREY

THE CHAIRMAN: The second number on the program is the Report of the Committee on Distributing Lines. Mr. P. M. Downing, of San Francisco, chairman, is not here, and the report will be read by Mr. L. A. McArthur, of Portland.

REPORT OF THE COMMITTEE ON DISTRIBUTING LINES

The term "distributing lines," when used in the ordinary sense, may imply lines of low voltage, but in the preparation of a report on this subject, we shall not consider voltage as being the limiting feature by any means, but shall classify as such all lines from which a general distribution service is given, regardless of the voltage. They will be distinguished from trunk and transmission lines only in that the latter are used to connect important generating and distributing stations.

The subject-matter contained herein relates especially to the Western States, and particularly to the Pacific Coast, where perhaps more has been done in the way of pioneering the distribution of electrical energy to rural and other sparsely settled districts than has been done elsewhere.

The past few years have brought about many changes in the method of transmitting and distributing electrical energy for power and lighting purposes. Voltages which a short time ago were not considered commercial possibilities are to-day being used not only on long transmission lines, but very generally for distributing purposes. It has not been long since 40,000 or 50,000 volts were considered the maximum at which a line could be operated safely and economically.

The continually increasing demand for electric power has made necessary the use of voltages as high as 100,000 or 150,000 for transmission purposes, leaving the lower voltage lines which were once used as transmission circuits to be used almost exclusively for distribution purposes.

Another condition contributing to the use of the higher voltages is that the rates are being continually reduced, while the territory served is increasing. This condition has forced operating companies to adopt a construction the cost of which will be the minimum consistent with good service. To-day there are a large number of companies operating general distributing systems in rural districts at voltages as high as 22,000.

Voltages higher than this can seldom be used to advantage except in the case of large consumers, owing to the high transformer cost. Where there are a large number of such custom-

ers whose requirements range from 1 to 15 hp., with only an occasional greater demand, a lower voltage can be used to advantage. Fifteen thousand and 11,000 volts have been adopted by a large number of companies, although 6600 volts is also being used in many instances. Forty-one hundred volts, being 2300 volts star connected, is perhaps the most satisfactory voltage for

FIG. 1. OUTDOOR POTENTIAL TRANSFORMER FOR USE ON 60,000-VOLT DISTRIBUTING LINES

use in districts where the load is not great enough to make the copper cost prohibitive.

In deciding on the voltage to be used in any new territory local conditions and the probable future demands for power will, to a very great extent, be the determining factor. The standard

ıd perhaps the best and most generally used voltage for cities ıd suburban territories is 4000, *i. e.*, 2300 volts, star connected. ransformers of this voltage can be had at a minimum cost.

In the congested business centers of the larger cities direct ırrent can sometimes be used to advantage. The only features, ›wever, which recommend a direct-current distribution over the

FIG. 2. 23,000-VOLT POLE TYPE METER HOUSE, FOR USE ON BRANCH DISTRIBUTING LINE

lternating current are: (1) The more satisfactory operation of irect-current motors, and (2) the ability to use storage batteries › improve the regulation and guard against interruptions to serv-ce. These advantages, however, are not so apparent now as

they once were. The improvements which have been made the operating characteristics of alternating-current motors lea but little to be said in favor of the direct-current apparat As a guarantee against interruptions to service, the mode steam turbine is much more reliable than the reciprocating engi Many of the companies receiving energy from hydro-elect sources now realize the necessity of maintaining a steam turbi station for both reserve and regulating purposes.

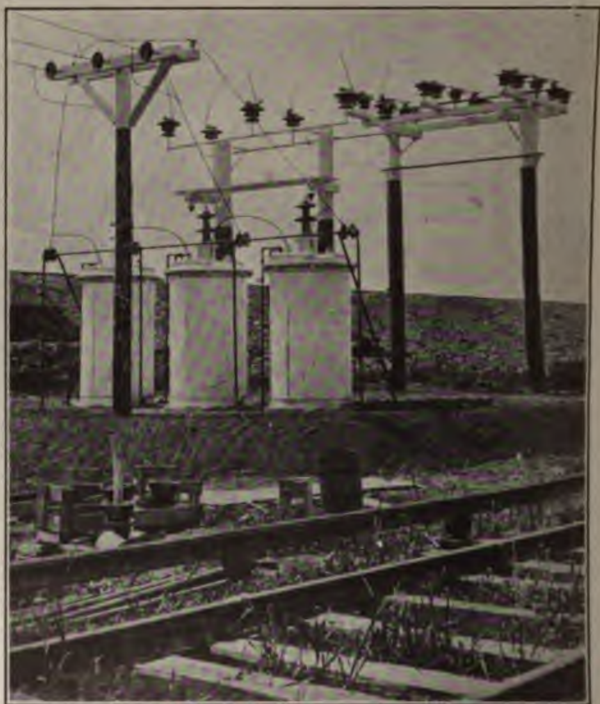

FIG. 3. OUTDOOR TRANSFORMER INSTALLATION FOR 60,000 TO 2300-VOLT SERVICE

Opinion as to the best connection to be used on transforme seems to be about evenly divided between the delta and the sta On lines up to 15,000, which is about the limiting voltage fro which small services can be supplied economically, the star co nection with grounded neutral seems preferable.

If a single-phase service is required, the neutral can, to lvantage, be run out from the station to carry the unbalance. the event of single-phase service being required in an isolated ction only of the system at a considerable distance from the ation, and where the expense of carrying the neutral the entire stance from the station would not be justified, an artificial neual may be established locally. By keeping the load in the disict reasonably well balanced between the three phases, only

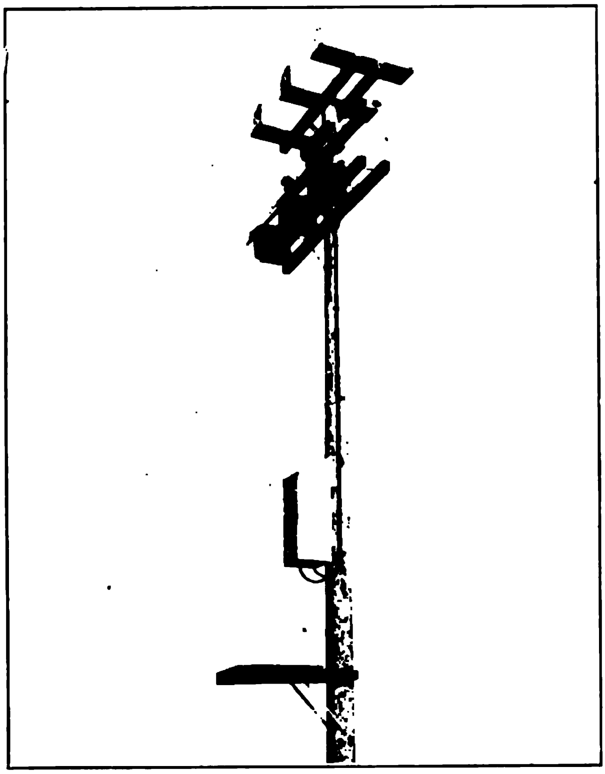

FIG. 4. 11-KILOVOLT POLE TYPE METER INSTALLATION FOR USE ON BRANCH LINES

ie unbalance would be carried through the ground. From an perating point of view, there is no objection to carrying this ibalance through the ground. Objection is, however, some-

Fig. 5. Pump House, Meter Box, Transformers and Disconnecting Switch Receiving Service from an 11,000-Volt Line

Fig. 6. Small Concrete Substation for Stepping from 60,000 to 11,000 Volts for Country Distribution

Fig. 7. 2300-Volt Pole Meter Installation for Use on Branch Lines

times raised to this method of operating, by the telephone, telegraph and signal companies on account of inductive interferences with other circuits in the immediate vicinity of the power lines.

The type of construction used on distributing lines has not changed to any great extent during the past few years. For the

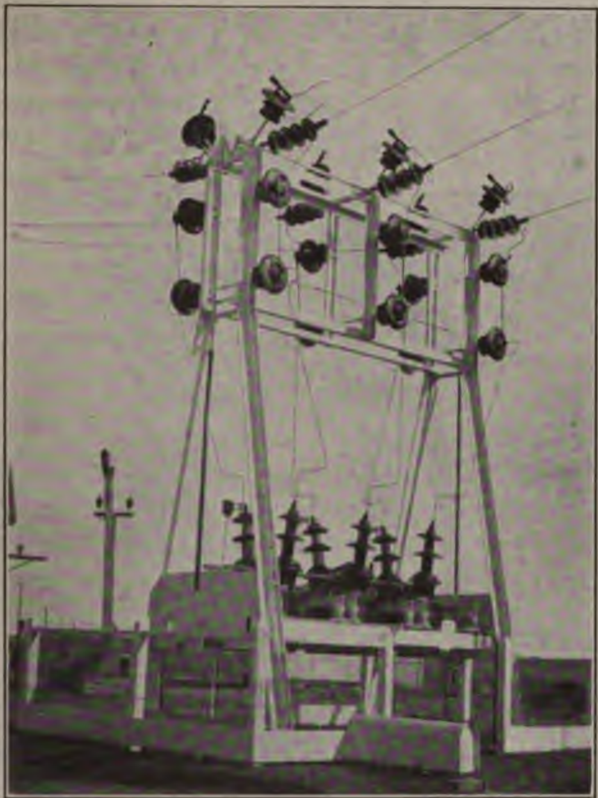

FIG. 8. 60-KILOVOLT OUTDOOR AUTOMATIC OIL SWITCH WITH BY-PASSING AIR SWITCHES

lower voltage circuits, *i. e.*, those operating at not more than 22,000 volts, the single flat-arm construction has been most used. Where it is desired to carry two circuits on the same line of poles, either of two constructions can be used: (1) The conductors of the two circuits may be supported on two arms to form two triangles on opposite sides of the pole; or, (2) the

two conductors may be placed in the same plane either vertically or horizontally. A safe and thoroughly substantial construction for the very high voltage lines can be had by supporting the two circuits on suspension insulators in vertical planes on the opposite sides of the pole.

For voltages up to 22,000 the pin type insulator has proved very satisfactory. From this voltage up to 60,000, both the pin and suspension types have been used. For voltages above 60,000 the suspension type is used almost exclusively. The objection to the use of suspension type insulators on voltages between 22,000 and 60,000 is the greater first cost. This, however, should not

Fig. 9. 60 Kilovolt Vertical Break Disconnecting Switches for Opening Branch Lines

always be the determining factor in deciding the construction to be used on a line, especially if the service is important and is to be supplied by a single circuit. On the Pacific Coast and particularly in the sections where the salt fogs are prevalent, the suspension type of insulator is to be recommended. The reason for this is that it has fewer air pockets in which dust and dirt can collect. During the months from June to November there is little if any rainfall with the result that considerable dirt accu

ıulates on the surface and under the petticoats of the insula- ›r. The salt fogs or rain coming into contact with this dirt ›rm a leakage path which is very apt to cause trouble. The fogs re worse than the rain, as practically the entire surface of the ısulator will be wetted without washing off any of the dirt, 'hereas with the rain the top and outer portions of the petticoat re washed clean and the inner parts are left fairly dry.

The only way to overcome this trouble is to clean the insu-

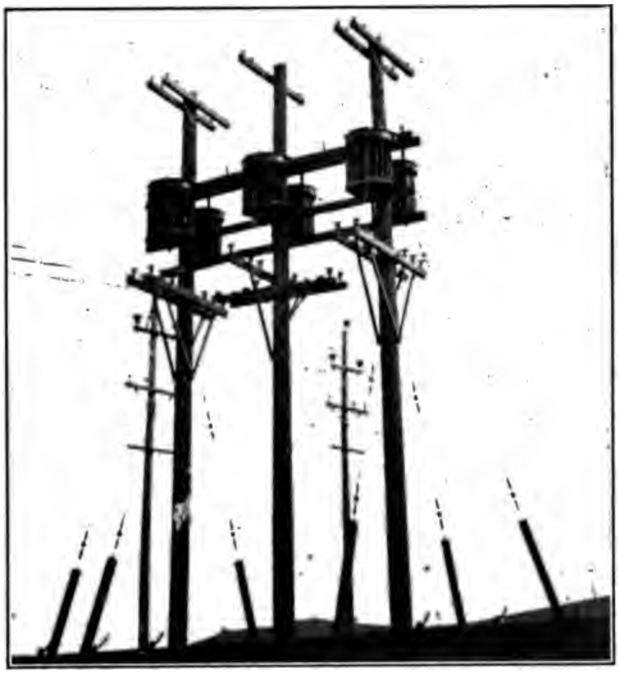

FIG. 10. 11,000-VOLT MOTOR TRANSFORMERS MOUNTED ON POLES

ıtors by wiping them. In some sections this dirt and salt fog ondition is so bad that even the telephone and telegraph circuits ecome at times inoperative until the insulators are cleaned.

A large portion of the suburban business consists of reclam- ıation, irrigation and small domestic motors. To give service of his kind requires a comparatively large mileage of lines per .orse power of connected load. To keep the investment down to

a point where the business to be had would justify the first cost of the installation, it has been necessary to construct lines at a minimum cost. A very satisfactory construction consists of 30 or 35-ft., round, white cedar poles, spaced 15 per mile, with the three conductors carried in a horizontal plane at the top of the pole.

Very often, where the load is small and the voltage regulation is not of too great importance, a considerable saving can be made by the use of iron wire, instead of copper or aluminum. This has been found to give equally as good service as the more

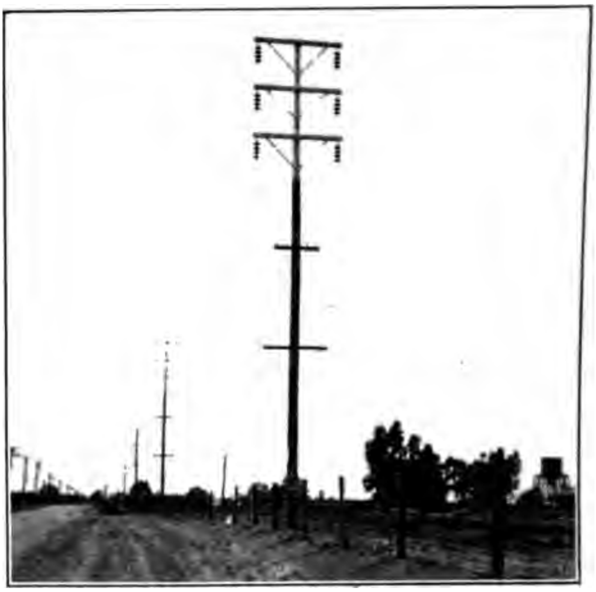

FIG. 11. DOUBLE-CIRCUIT 60,000-VOLT BRANCH LINE WITH 2300-VOLT AND TELEPHONE LINES BELOW

expensive conductors, providing, of course, it is not over-loaded. Outside of cities and communities, where the use of insulated wire is required by ordinance, it is the almost universal practise to use bare conductors. Service wires leading into buildings are always insulated.

Of late years there has been a strong and growing tendency for legislative and other governing bodies to regulate line construction details. A number of States have done this by direct

legislative enactment, while others have vested that authority in commissions having control of public utility affairs.

In California where the State Railroad Commission has control of all public utilities, the specifications for overhead crossings for electric light and power lines over railroads, street railroads, telephone and telegraph lines, etc., as adopted by the National Electric Light Association, have been accepted for crossings of lines carrying voltages of 15,000 and over. A compliance with these specifications will, in some respects, improve the crossing construction, but it is believed by many engineers that certain changes could be made that would materially lessen the first cost of the crossing without in any way impairing its efficiency.

Line extension estimates are generally made on the supposition that the gross revenue for the first three years will equal the cost of the investment. In some instances, however, when the extension is into new territory, where there is a probability of other business being developed, or where the demand is large and is to be supplied on long-term contracts, the investment can be made on a more liberal basis. In other words, the extension might be made on the basis of the gross revenue for five or an even greater number of years equalling the investment. Sometimes the customer is required to advance a portion or all of the first cost of the extension and have it rebated to him: (1) within a certain fixed period of time; or (2) on the basis of a certain percentage of his monthly bill to be refunded.

Arrangements of this kind are oftentimes very satisfactory when made with customers whose requirements will ultimately be large, and who, perhaps, should have the benefit of the lower rate for their present small demands. The percentage of the power bills rebated averages from 20 to 25 per cent.

DISCUSSION

Mr. E. H. Negley, Canton, Ohio: I have a question to ask. Is it correct, as stated on page 12, that 35-foot poles are spaced 15 per mile.

Mr. Lewis A. McArthur, Portland, Ore.: It would certainly be pretty long spacing.

Mr. Fred G. Hamilton, Visalia, Cal.: Regarding the spacing of poles I will say that it is the custom of the companies

in the San Joaquin Valley to space their poles from 300 to 440 feet apart. On the 300-foot spans we are using 30-foot poles; on the 445, 35 to 40-foot, using poles five feet higher at public crossings on highways.

MR. MCARTHUR: There is only one thing that I might say, which is that in Oregon and Washington we very seldom use poles less than 35 feet high. A 30-foot pole would be too short for that country, for the reason that a great many farmers in the Oregon district use alfalfa hay-stackers, a sort of hay-derrick, like a gin wagon, and when they foul the line there is generally some trouble. Very often they will get themselves foul of a 66,000-volt line. We have had, in three years, three or four farmers killed simply because of carelessness in getting their hay derricks tangled up in high-tension systems. We do not find it advisable to put in poles less than 35 feet high for 6600-volt distribution, and we space them anyhere from 175 to 300 feet apart, depending upon the territory, the character of the soil and how heavy the work is.

THE CHAIRMAN: The next number on the program, originally scheduled for yesterday, is a paper entitled, Developments in Protective Apparatus, by Mr. J. N. Mahoney, of Pittsburgh.

DEVELOPMENTS IN PROTECTIVE APPARATUS

Under the above rather comprehensive title this paper will describe a number of improvements that have been made in oil circuit breakers, carbon circuit breakers and lightning arresters. The manufacturers of this apparatus have recently done a great deal of research and development work along these particular lines.

This has been brought about by the unusually high voltages, large capacities and length of lines now in common use under the recent consolidations of numerous distributing systems. Tests have been made under service conditions to demonstrate the efficiency of these improvements.

OIL CIRCUIT-BREAKERS

GENERAL POINTS OF DESIGN

In an oil circuit breaker there are three qualifications called for: (1) It must be insulated for the voltage at which it is rated, (2) it must have sufficient carrying capacity for its rated current, and (3) it must have sufficient circuit breaking capacity to meet the conditions at the point where it is applied and to suit the character of the service.

Assuming the first two qualifications to be met in the product of the well-known manufacturers, at least on apparatus up to voltages that have been standard for some years, the necessity for the improvements described was to meet the third qualification under the new conditions.

BREAKING CAPACITY

Oil breakers are made in a variety of types and sizes for various breaking capacities, ranging from a switch capable of operating in connection with a plant of but a few hundred kilowatts to those for service on systems of several hundred thousand kilowatts capacity. The breaking capacity, or, as it is variously stated, the ultimate breaking capacity or rupturing capacity, usually takes into consideration only the kilovolt-ampere capacity of the generating or synchronous apparatus that may supply the breaker in event of a short circuit. Other factors are: the consideration of the inherent reactance and characteristics of appa-

ratus and the known reactance of the lines between generating apparatus and the breaker, which tend to reduce the short circuit current that reaches the breaker; also the "speed of operating" characteristics of the breaker itself; the relation of the breaker to the lines and apparatus in a particular system; and the method of tripping the breaker or otherwise obtaining automatic operation.

To cite examples of the speed of operation of breakers, it may be said that breakers tripped directly by series-trip coils or trip coils directly fed from series transformers and acting directly on the breaker mechanism, will act on short circuit in approximately two to two and one-half cycles on 25 cycles, or approximately one-tenth of a second, especially when the breaker mechanism is equipped with means for accelerating it at a rate greater than the action of gravity. Breakers, tripped by what is known as a shunt-trip coil in some cases supplied with direct-current through relays which are in turn acted upon by coils in series with the load current, or whose coils are supplied from series transformers, take a much greater time to act. This will vary in length with the form of relay used, with the form and inertia of the tripping mechanism used, and with the form of magnetic circuit used in the trip magnet. The writer's experience is that the least time in which one of these combinations will act is approximately one-quarter of a second or 6 cycles of a 25-cycle circuit, and may be almost any period greater than that, determined wholly by the type of breaker mechanism and method of automatic tripping.

The characteristics of the apparatus supplying a circuit breaker under short-circuit conditions are closely related to the speed of operation of the breaker and the tripping means employed. Alternating-current generating apparatus will develop from five to fifty times full load current on direct short circuit, limited only by the inherent reactance of the apparatus itself, on the first few waves immediately subsequent to the application of the short circuit. The tendency of the short-circuit current is to decrease thereafter until at the end of some small period—usually in from one to two seconds—it reaches but two to three times full load current, which factor is then known as the "sustained short-circuit current." The rate of this decrease varies with the different forms of machines, even with those having the same maximum and sustained short-circuit current.

In a system of considerable size it may be noted that with considerable reactance, provided either artificially or naturally by means of the lines and transformers in circuit between the generating apparatus and the breaker, short-circuit currents at the breaker may be constant, regardless of the method of tripping. This may be relatively small, compared with the same breaker situated on the bus bars at the generating plant. In the case of the breaker having considerable reactance between it and the source of power supplied, the method of tripping or speed of operation would not affect the current it would be compelled to break, and the characteristics of the generators would not have to be considered. In the case of a breaker situated close to the generating apparatus, all of the above factors come into consideration, even on breakers bearing apparently the same description of the method of tripping, such as, for instance, "instantaneous trip." As stated above, an instantaneous direct-trip breaker may work on the second cycle of a 25-cycle circuit when the current on short circuit is practically at a maximum; whereas, instantaneous relay trip breakers would not work earlier than in 6 cycles of 25 cycles. Considering this fact in connection with generators of widely different characteristics, and in some cases having a very steeply decreasing characteristic, the instantaneous relay-trip breaker would be compelled to break but a small portion of the current that a direct-trip breaker would be forced to do in the same location.

The location of the breaker electrically in the system affects the work that may come upon it in another manner. As an example of this might be mentioned two breakers at the ends of a high-voltage transmission line. Under the condition of a short circuit produced beyond the circuit breaker at the receiving end, this breaker, if it cleared the short circuit, would be compelled to open the circuit with a current flow limited by reactance of the generators and lines to the point of short circuit which, it is assumed, is just beyond the receiving end breaker. If the breaker at the station end cleared this same short circuit, it would be compelled to perform the same work as the breaker at the receiving end and in addition to take care of the stored energy in the transmission line which tends to re-establish or maintain a potential difference for a period immediately subsequent to the clearing of the dynamic flow of current in the circuit breaker.

Also, the insulating value of the oil in the breaker may be so
what impaired by the arc of the dynamic current immedia
preceding and before the circuit breaker has completed its c
of operation. In addition to the added work imposed on

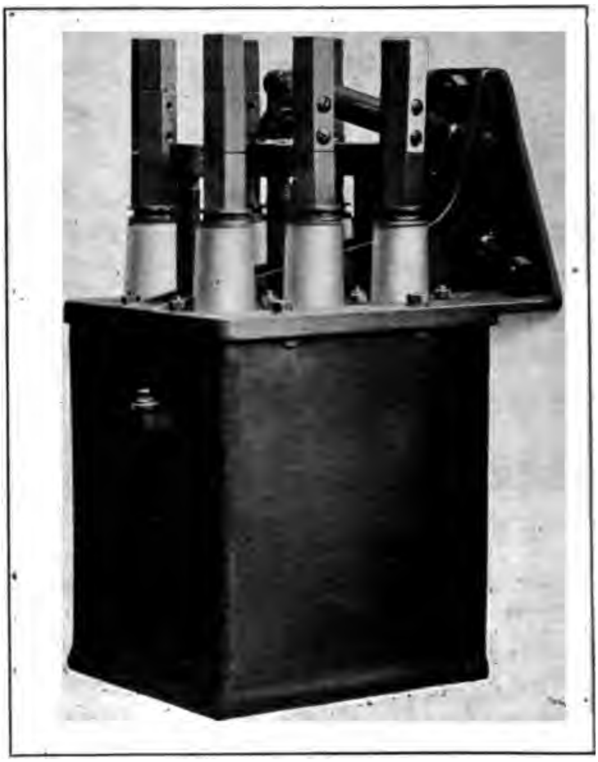

Fig. 1

breaker at the generating end, when it is located and opera
such a manner that the entire output of a relatively large
passes through and it is caused to operate under short-
condition, the stored energy in the generating equipment,
formers, etc., is dissipated therein. This is in addition to the
of circuit breaking, whereas when a number of lines and c
including other apparatus are operated in parallel with th
that may be in trouble, this energy is dissipated in the syste

It will be noted from the several foregoing factors which affect the application of oil circuit breakers that the standard rating covers only a given case; hence to make the best proposition for all conditions these ratings given should be exceeded in some cases and reduced in others, and the more data available, the closer the proposition can be figured.

MODERATE CAPACITY AND VOLTAGE TYPES

Fig. 1 shows a 3-pole, 500-ampere, 7500-volt switchboard or remote mounting oil circuit breaker, and illustrates a type of breaker for moderate voltages and capacities. It is made in switchboard or remote mechanical control mounting and hand or electrically operated. Attention is called to the unusually rugged mechanical design. It has vertical porcelain pillars for supporting the contacts and conducting details, the contact details being of the moving wedge and stationary finger type. The oil tank is of heavy steel plate and has lap-welded joints with the bottom flanged and welded on the outside of the tank sides. The lining of the tank consists of individual "micarta" sleeves for each pole of the breaker. The supporting frame of the breaker has a flange which encloses the upper end of the tank to restrain it from distorting under internal pressure. The tanks are deep in order to provide a considerable air space above the oil level for the expansion of the arc gases and to prevent the slopping of the oil from internal disturbance. The gases are vented through the clearance around the wooden operating rods of the frame. The porcelain pillars are clamped in position, as are also the conducting studs and contact details to the porcelain pillar, so that no babbitt or cement is used in the construction. Lock washers are used on the clamp bolts and conducting studs to hold these in position and prevent loosening from the vibration and hammer blows that are incident to the operation of the breaker.

The contact improvements consist in having the conducting tip on the end of the contact finger which engages the moving contact wedged surface, supported on the end of a thin steel spring permitting the contact automatically to align itself. This spring is shunted by a liberal sized copper leaf, which conducts the current from the finger head or tip to the terminal stud. The contact pressure is obtained by a second and heavier steel spring

provided on its end with a head which applies the pressure over the center of the contact tip of the finger. Several fingers are used per stud according to the capacity of the breaker. The initial position and contact pressure of the several fingers is determined by a steel stop mounted on the end of the contact stud and between the two sets of fingers. The stop determines the opening between the fingers into which the wedge enters and prevents any play of the moving contact from causing trouble by compelling it to enter between the fingers. A plunger arcing tip, a part of the stationary contact, makes a butt contact engagement with a brass cap bolt screwed into the moving cross bar. This butt arcing tip maintains contact for a considerable distance after the main fingers and moving wedge have separated. This distance is predetermined by the stop between fingers and is an improvement on the older forms in which no stop or separate arcing tip on both members was provided.

The pillars above the frame together with the exposed terminal on it are provided with a moisture-proof micarta tube for use where the operator does not otherwise insulate these exposed live terminals.

Breakers such as those just described are made in capacities up to 600 amperes and as high as 15,000 volts.

HIGH CAPACITY SELF CONTAINED MULTIPOLAR TYPES

There has been considerable development of medium voltage, high capacity, oil circuit breakers in which the several poles of the breaker are all mounted on one metal frame, which can be supported on a wall or other framework, complete with its electric operating mechanism, or operated mechanically by the regular remote control mechanism. This type of breaker has a separate tank for each pole, as is usual with high voltage and high capacity breakers in which the several poles are on separate frames. The mechanical details are made very rugged to withstand the high internal pressures due to opening heavy short circuits. The porcelain insulating details for supporting the contacts are of the pillar type, substantially clamped in position, and the contact details are in turn clamped to the porcelain pillars so that repairs or replacements may be made conveniently. These points are illustrated by referring to Figs. 2 and 3. The range of capacities is from 300 to 2000 amperes and up to 25,000 volts.

In this type of oil breaker and the several others herein-
ter mentioned, above 300-ampere capacity, the contacts are what
known as the butt type laminated brush with butt type solid
cing tips. This brush contact is the same as that used in
modern high class carbon circuit breakers. This form of
in contact has a very high contact pressure, usually around
o lb. per square inch, and is designed to be automatically

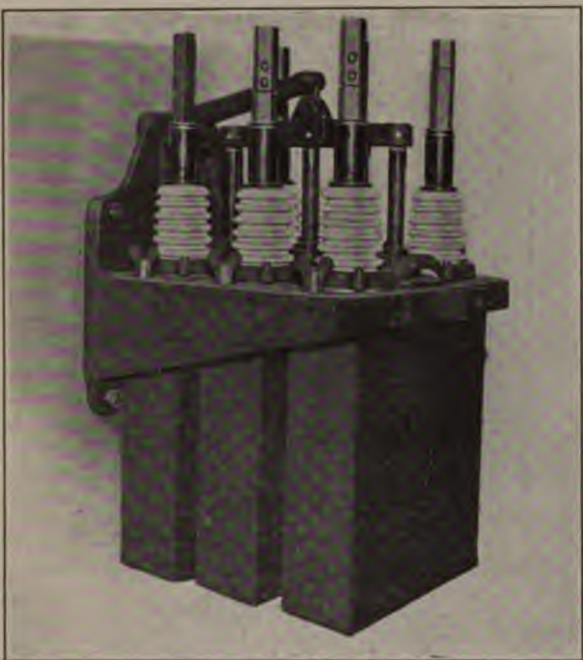

Fig. 2

lf-cleaning at the contact surfaces when operated. The high
ntact pressure as well as the exceptional wiping action both
ntribute to the self-cleaning feature in a degree not obtained
any other form. It will be noted that the contact surfaces of
th the main and arcing contacts are of the butt type, and all
e pressure on these surfaces tends to throw the contacts apart,
, in other words, to open the breaker.

The butt arcing tips are placed outside of the main con-
cts so as to take into consideration the magnetic blowout effect

caused by the current passing down through the stud, across the contacts and up the opposite stud. This tends to blow the arc outward from the center away from the main contact and off the outer edge of the butt arcing tips. This action together with the gravity or buoyancy of the arc gases, cause them and also the arc to be rapidly driven outward and upward away from the contacts and supporting bushing, and to assi

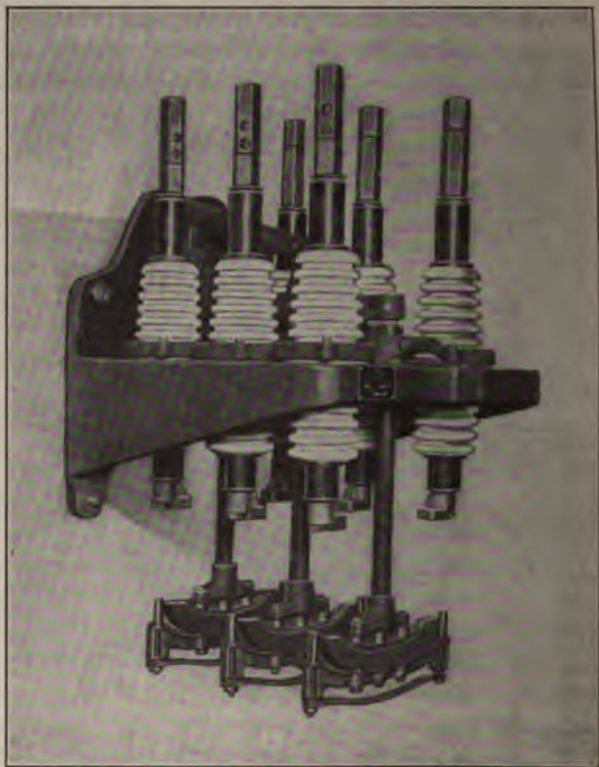

FIG. 3. HIGH CAPACITY UNIT FRAME PIPE FOR CIRCUIT BREAKER

the successful operation of the breaker under short circuit ditions.

There has been developed a complete line of oil ci breakers primarily intended for mounting on pipe or struc frame work or on a wall, eliminating the necessity of encl structures. They can, however, be mounted in structures

ed. This structure can consist of mounting each pole in a ate cell, or several poles can be mounted collectively with the ting mechanism in a single cell, which will segregate the

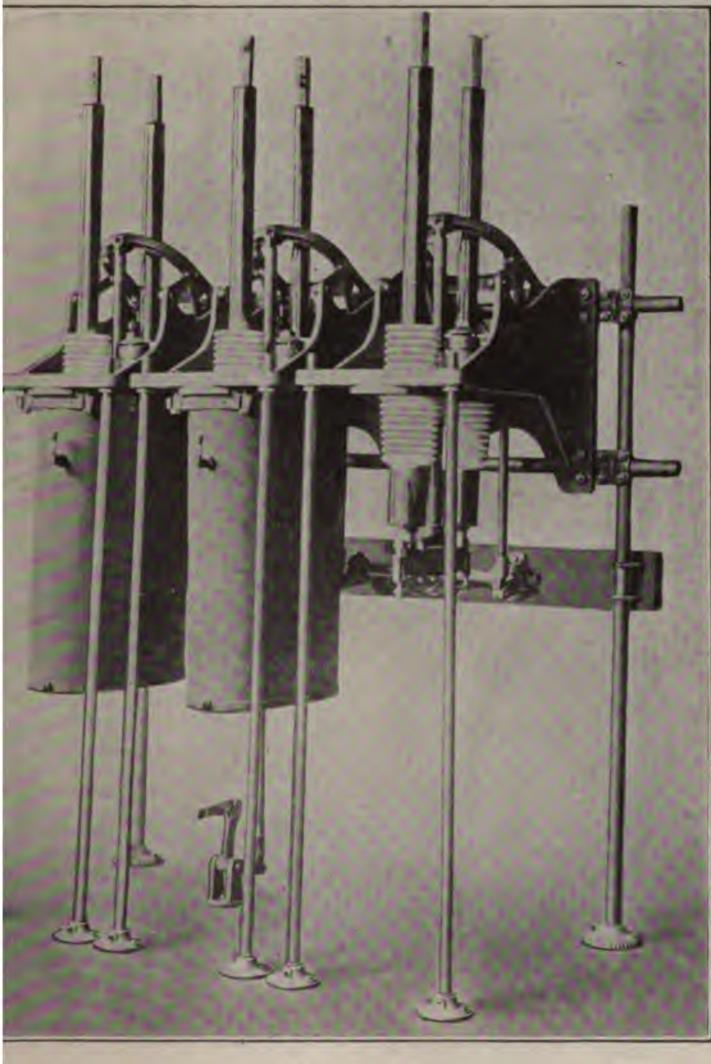

FIG. 4

lete unit from other similar units. The latter mounting is rable where this type is placed in a structure. This form of

breaker is illustrated in Figs. 4 and 5, which show a hand ope
600-ampere, 35,000-volt, 3-pole breaker, and a 7500-volt,
ampere, electrically operated, 3-pole breaker respectively,

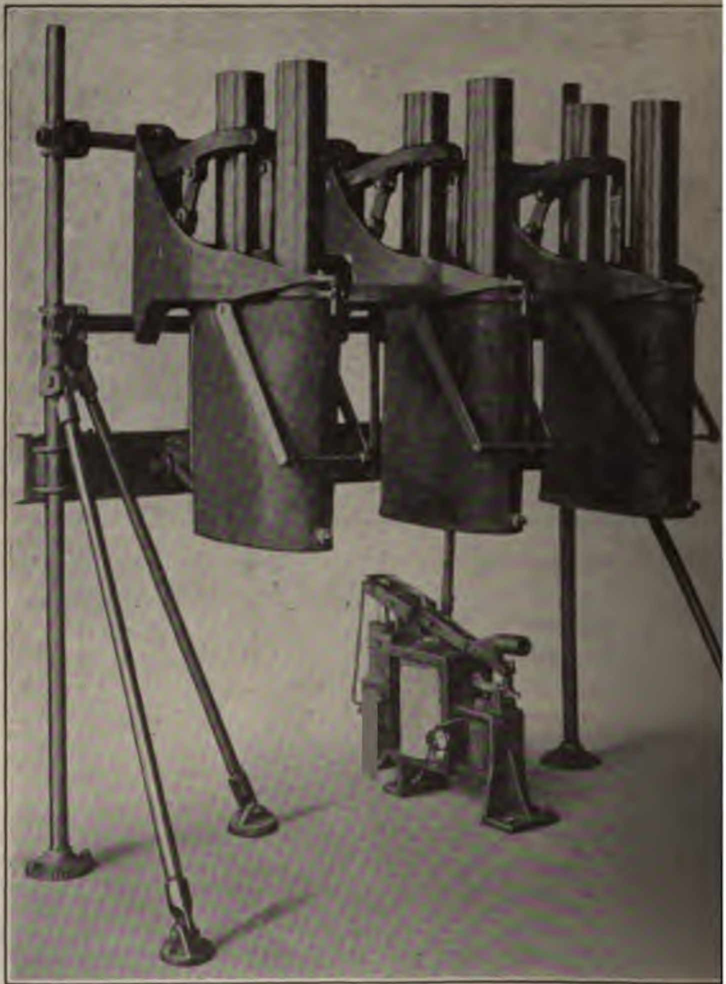

FIG. 5

mounted on pipe frame work. Breakers of this type have
made in two frame sizes, in capacities up to 4000 ampe
15,000 volts, up to 1200 amperes at 25,000 volts, and up t
amperes at 35,000 volts.

this and the following types of breakers an elliptical form
is used, having no flat surfaces except at the bottom. The
e within the tank is restrained by the metal under tension,
team-boiler practise, and not in deflection, as with the rect-

FIG. 6

tank. The metal in these elliptical tanks is 1/10 in. to
in thickness. All of the joints are lap-welded and the
is flanged outside of the tank proper and lap-welded
. This form of construction causes the pressure within
k to place counteracting tension stresses in the bottom to

balance the deflecting stresses caused by the pressure directly acting on the bottom. The supporting frame for the tank is made to enclose the tank flange in such a manner as to keep the tank

FIG. 7

from spreading when under pressure from the gases of a short circuit. An air space is provided above the oil either in the tank chamber or a chamber in the supporting frame, to take care of the gases caused by the arc and to reduce the pressure in the tank. A baffle vent fitting is provided for the escape of gases.

FLOOR MOUNTING AND OUTDOOR, HIGH VOLTAGE, HIGH CAPACITY TYPES

It has become quite common practise to make certain breaker installations in high voltage and high capacity work without any form of enclosing structure. The breakers are usually single-pole units mounted on the floor or gallery, and operated

ough either remote hand controlled mechanism or by remote ctrical control, by which any number of units can be coupled make a breaker of the required number of poles. This same m of breaker, when provided with "rain shields" on the termi- bushings and appropriate housings for the mechanism, is also d for outdoor work. Fig. 6 illustrates a hand-operated breaker the 3-pole indoor type for 11,000 to 44,000-volt service, 300 l 600-ampere capacity. Fig. 7 illustrates a 3-pole electrically

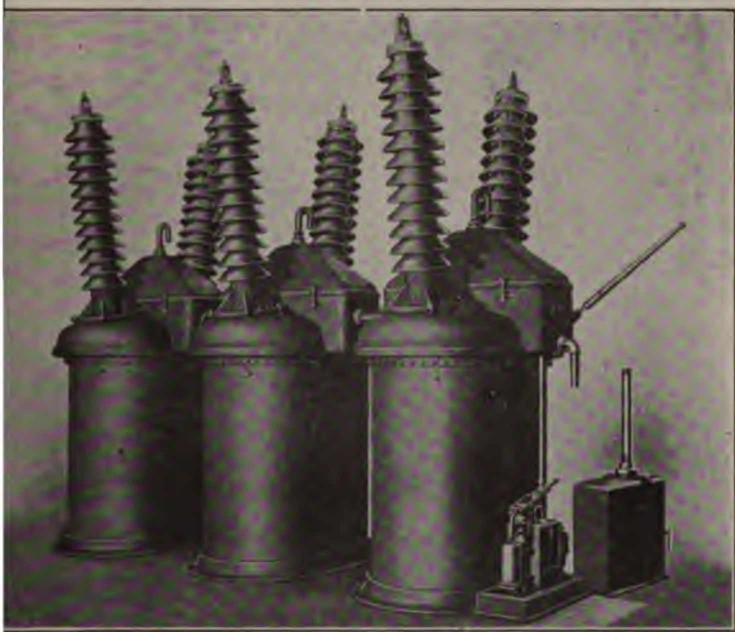

FIG. 8

rated indoor type breaker of the 66,000-volt form, 300 and -ampere capacity. Fig. 8 illustrates a 120,000-volt, 300 or -ampere capacity and electrically operated 3-pole breaker ar- ged with the weather-proof details for outdoor mounting.

REACTANCE TYPE

In order to meet the condition where extremely large power acity at high voltage has to be controlled with certainty under conditions, the reactance type breaker has been developed.

This breaker consists in reality of a double circuit breaker ha
two complete sets of contacts and self-contained reactance
included in and operated by a single mechanism. One s
known as the main contacts which normally conduct the

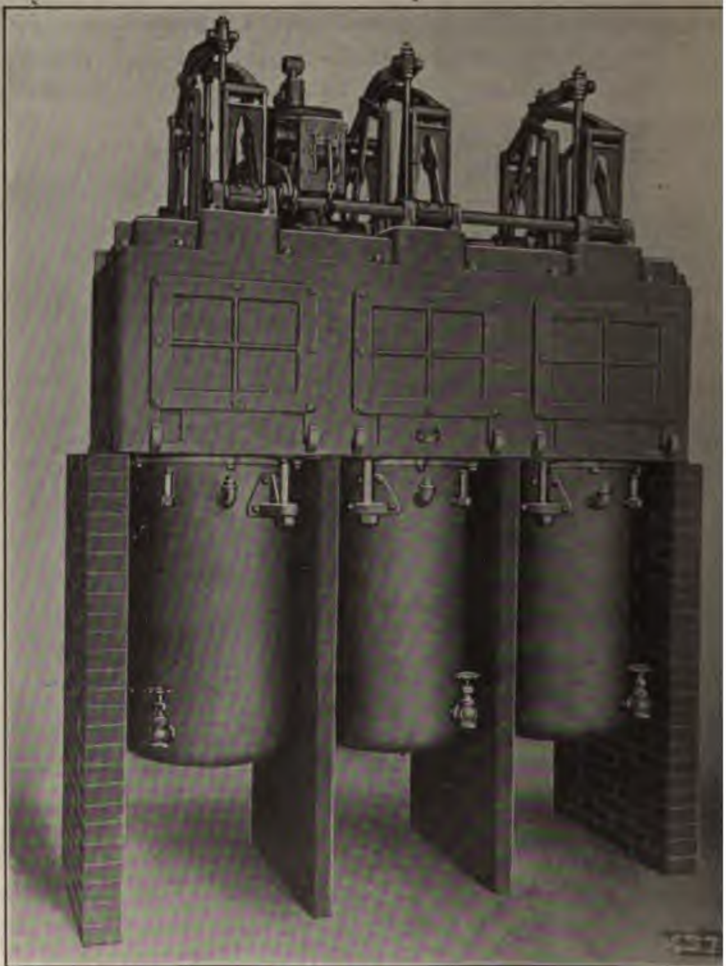

FIG. 9

current when the breaker is closed. These are shu
by appropriate reactance coils and an additional set of
tacts which carry current only during the operation of the bre

Fig. 10

while in the act of closing or opening. Two forms of this breaker are illustrated herewith. Fig. 9 shows a 25,000-volt, 1200-ampere, 3-pole breaker arranged for cell structure mounting. Fig.

10 illustrates a 110,000-volt, 600-ampere, 3-pole breaker of the indoor floor mounting type. The breaker shown in Fig. 9 has round tanks formed complete from a single piece of steel without joints.

CARBON BREAK CIRCUIT BREAKERS

Carbon circuit breakers are now made in standard sizes from 3-ampere to 24,000-ampere capacity, and up to 1500 volts direct current. The problems of design vary considerably with the circuit breaking ability and conducting capacity required. In the highest class of circuit breakers all of the contacts are of the "butt" and "wiping" form under considerable pressure to afford large capacity per square inch of contact and good self-cleaning action in operation. The mechanism is also designed so that all of the mechanical forces applied to the several contacts shall assist in opening the circuit breaker.

In order to meet the requirements of circuits and systems having moderate capacities, a circuit breaker of the general design shown in Figs. 11 and 12 has been constructed. In this form the main switch arm carries laminated brush-type contacts and also has a spring contact member bearing on the main contacts in addition to the brush. This is known as the secondary contact and it is arranged to remain in engagement after the laminated contact has broken the circuit, but it in turn interrupts its circuit before the carbon contacts have separated. This provides two steps of relatively increasing resistance in the progressive movement of opening the circuit, so that the liability of an arc forming on the main contacts is decreased further than where the carbon auxiliary contacts only are used. Circuit breakers of this class are made in capacities up to 800 amperes.

Referring to Fig. 11, one of the improvements noted is the particularly rugged construction secured by the use of the punchings of wrought metal throughout. This type of circuit breaker is designed primarily for small switchboard and industrial service up to 750 volts direct or alternating current. The figure shows a 2-pole "double-arm," "common-trip" breaker of this type with an overload coil in each line of the circuit and an undervoltage trip. This form is particularly adapted to motor-starting purposes on a 440 or 600-volt system having a grounded neutral, and dispenses with the use of a separate switch. One pole can be closed at a time, and if a short circuit exists, the first pole closed

will trip when the operator closes the second pole. The under-voltage trip is for the purpose of disconnecting the motor from the line on cessation of voltage in the motor supply circuit. The usefulness of the overload coils in each line, in this instance,

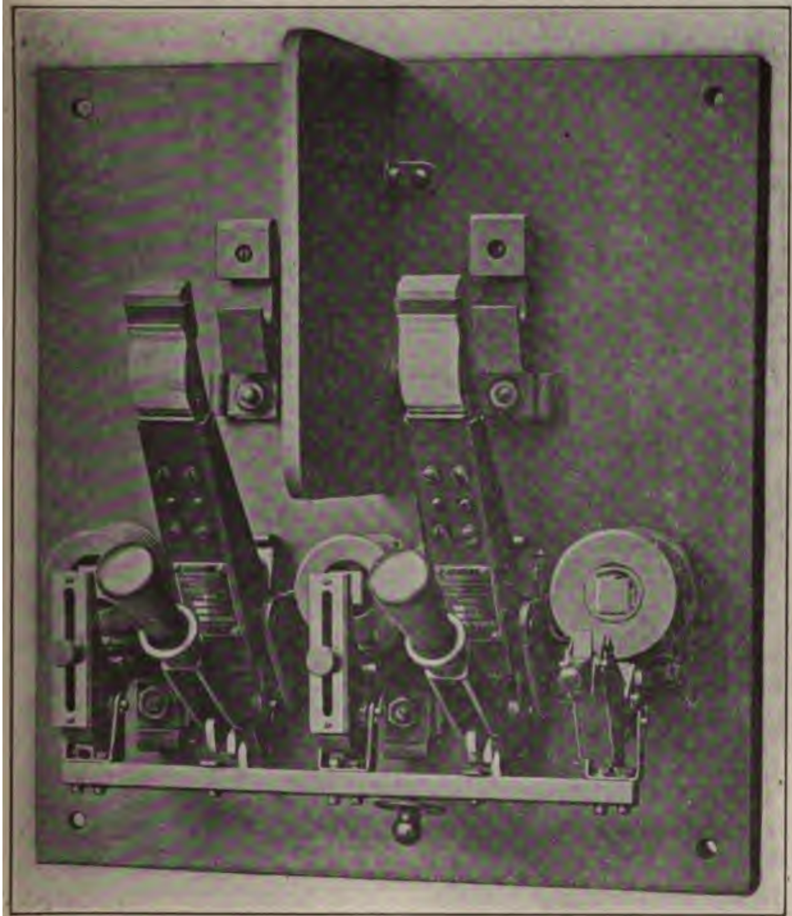

FIG. 11

with a grounded neutral system is evident, as a short circuit could be produced from either line to ground. Either overload or under-voltage will trip both poles of the breaker through the common trip bar.

A prime requisite of a line of automatic circuit breakers is that they shall be designed so that they can be actuated by over-voltage, under-voltage, under-load, reverse current and shunt trip, in addition to plain overload, or any combination of them where required. In Fig. 12 is shown a 4-pole circuit breaker actuated by overload coils in two of the lines and in addition by under-load, over-voltage, under-voltage, and shunt trip. It also shows the use of barriers, which are recommended where the voltage is above 300. On the second pole, counting from left

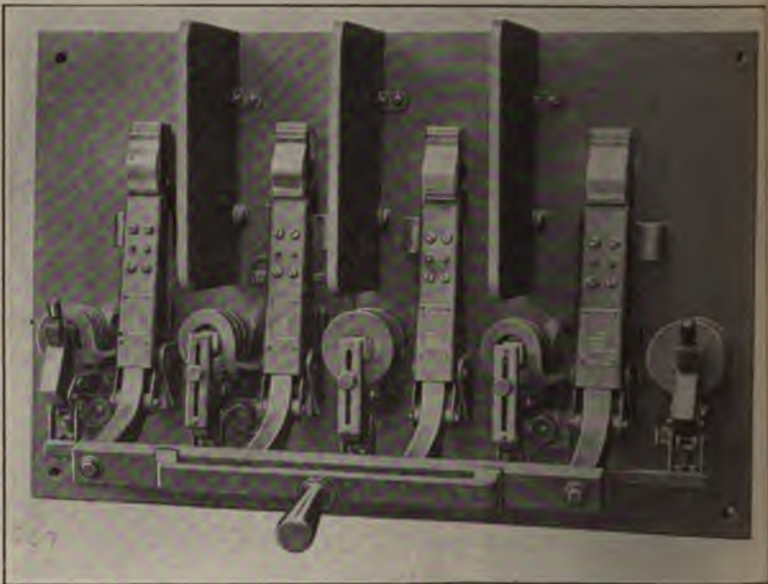

FIG. 12

to right, shunt trip cutout contacts are shown, which open the circuit of the shunt trip after it has performed its function of tripping the circuit breaker. These contacts can also be used to close and open circuits for indicating lamps, to show the operator at a distance whether the circuit breaker is open or closed.

One of the main problems in carbon circuit breaker design is to provide a circuit or number of circuits with increasing resistance in shunt to the main contacts to relieve them of the possibility of arcing. The final shunt circuit must also be capable

taking care of the arcing without excessive injury to itself. n modern heavy railway systems from 30,000 to 60,000 amperes e obtained under short-circuit conditions. It is readily seen at one-thousandth of an ohm difference in the resistance of one

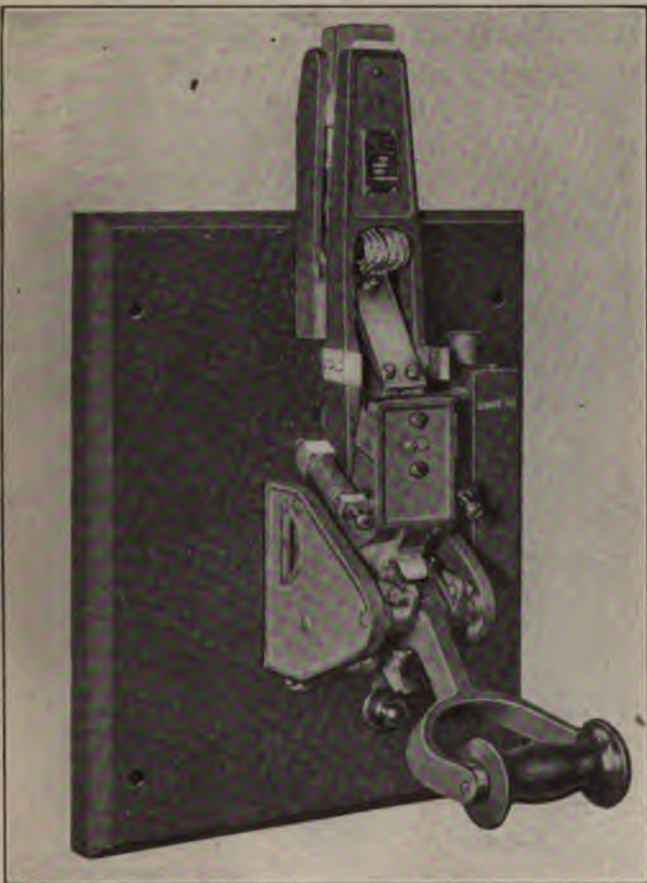

Fig. 13

f these shunt paths would cause a difference in potential of from o to 60 volts, which is sufficient to establish an arc. This equirement calls for several steps between the main contacts and he opening of the carbon arcing tips in circuit breakers of very igh circuit breaking ability. This in turn requires a construction

which will have dimensions and characteristics for controlling value of resistance in the several shunt circuits. In the cir breakers illustrated it will be noted that the number of these tures included is in accordance with the character of the ser to be performed.

In Figs. 13, 14, 15 and 16 are illustrated several sizes forms of a line of circuit breakers having conducting capaci from 200 to 24,000 amperes, designed to meet the condition the heaviest service now known. By referring to Fig. 13, wh

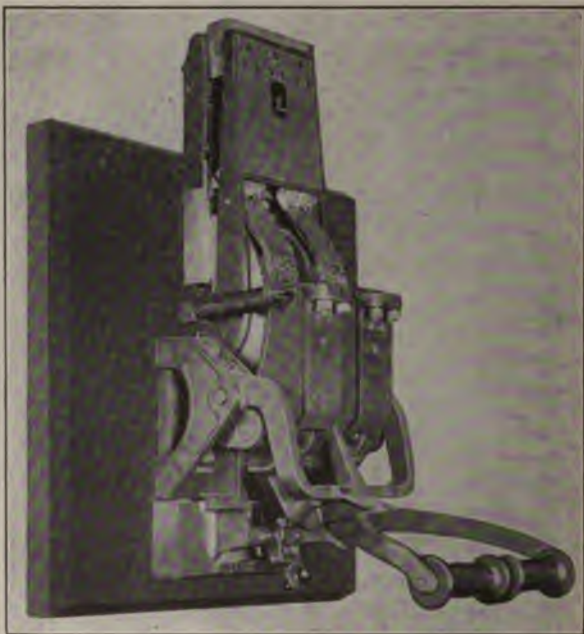

Fig. 14

illustrates the general form taken by this type in capacities f 200 to 2000 amperes, the several steps in the progression opening the circuit may be noted. In addition to the r brush, a very substantial secondary contact is placed imm ately above. The details of this are connected by flexible sh to the lower end of the tertiary contacts, which are of co mounted on the same supports as the carbon arcing cont

hese contacts are so mounted as to be self-aligning in order to dapt themselves automatically to good contact relation with a imilar set on the carbon arm of the moving element, and to fford at the same time, a wiping action to insure a good, elf-cleaning contact. The carbon itself is heavily copper coated nd machined at all points where it comes in contact with the

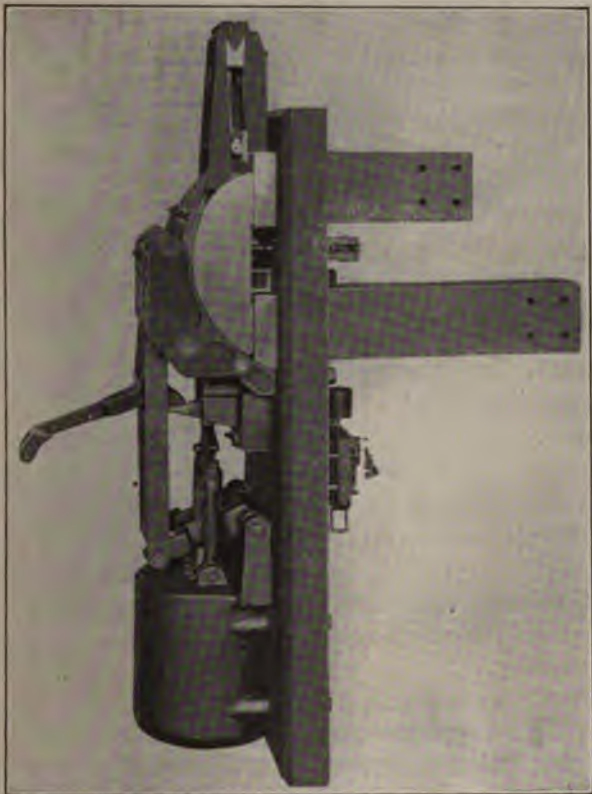

FIG. 15

ertiary contact and the conducting supports. All of these features are for the purpose of affording several steps in the openg of the circuit, each one of which will give a correct relation the resistances of the several successive shunt circuits up the point of inserting the resistance of the carbon arcing conts, which is relatively high. These features in themselves

are quite distinctive from similar features in smaller circuit brea
ers that are not designed to meet such extreme conditions.

In Fig. 14, which is an 8000-ampere hand-operated circ
breaker, is illustrated the general form which this type tak
in capacities from 3000 to 9000 amperes.

Figs. 15 and 16 illustrate an electrically operated 12,0

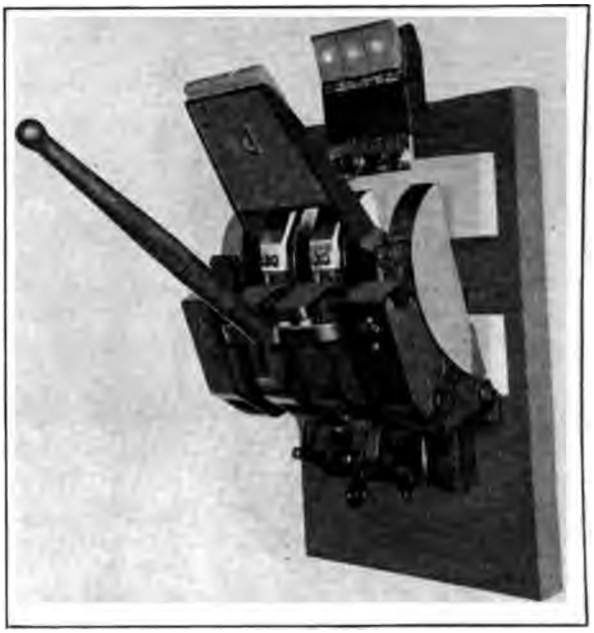

FIG. 16

ampere, and a 16,000-ampere hand-operated circuit break
respectively, of this general type, and particularly sh
the method of utilizing conducting material most efficien
These circuit breakers are composed of four units mounted w
considerable space between them for efficient ventilation and
reducing the skin effect when used on alternating-current w
The similarity in design of the details of construction in t
sizes to that shown in Fig. 13 of the lower capacities of
same type, will be noted. The ventilated form shown in F
15 and 16 is made in capacities from 10,000 to 24,000 amper

The contact studs, which project through the panel, are in two forms, which are known as round or "solid," and "laminated" studs. The round stud consists simply of a bar of copper, integral with the contact head and threaded to receive the clamping nuts passing through the switchboard panel. The laminated construction is particularly adaptable to alternating-current and to large capacity direct-current work, and is illustrated in Fig. 15.

LIGHTNING PROTECTION

In lightning protection the aluminum electrolytic arrester stands supreme, and is rapidly displacing all other types wherever the larger investment is justified by the apparatus to be protected or the severity of the conditions to be met. The custom of daily charging, that is now pretty well established, results in general freedom from the trouble of dissolved off films and resultant excessive charging currents that once existed. The use for several years of an inorganic electrolyte has shown its great superiority over any organic electrolyte, because of its freedom from the tendency to form a mold and siphon the solution out of the trays that is so characteristic of organic electrolytes such as tartrates. The shape of the aluminum trays themselves is of great importance, much better results being obtained by the use of annular trays, which offer a larger area to the electrolyte than other standard shapes, and allowing the cooling oil to circulate up through the center of the tray columns where it is most needed.

When electrolytic arresters were first used all efforts were directed to making them rugged and reliable. Now that these results have been obtained, the present tendency is toward refinement of design. The size of the pipe frame structures that carry the horn gaps is being reduced as much as possible to save space, while the size of tanks is being reduced and their insulation improved by the use of insulating linings.

When electrolytic arresters are charged, the arrester acts as a condenser in series with a spark gap, and there is a tendency to set up high frequency oscillations, which may cause injury to the terminal apparatus. This may be especially severe where the film has been partially dissolved and the charging current is abnormally high. However, with daily charging the film should never fall so low as to endanger well built transformers. When,

on the other hand, electrolytic arresters are used for the protection of generators directly connected to the line whose slot insulation is necessarily comparatively weak, or for the protection of cable systems, whose stored electrostatic energy is great, it is better to use a so-called "charging resistance" to limit any excessive flow of charging current and damp out any tendency to oscillations. Such a resistance is so connected in that it does not interfere with the freedom of a lightning discharge. While with proper care of the arrester this charging resistance is not required, except in the cases mentioned, it can of course be used with any electrolytic arrester as an added precaution.

While the electrolytic arrester affords better protection than any other type, there are many cases where an arrester of its high cost is not warranted or where lack of attendance would make it impossible to charge the arrester daily. For these cases the type of arrester making use of a number of non-arcing metal gaps, together with series or shunting resistances or both, affords excellent protection and has been used for many years with success.

Every year transmission line voltages grow higher and arresters have to be designed to keep the pace. Arresters of the electrolytic type are now available up to 165,000 volts, which is the highest voltage so far adopted commercially.

DISCUSSION

MR. R. V. WARD, Joliet, Ill.: I want to ask of Mr. Mahoney if he has any detailed information to offer in regard to protecting the pole type of switches from lightning, particularly the terminals inside of the cages.

MR. MAHONEY: Of course, that would refer to a particular type of design. Lower voltage switches of course always have a shorter distance between terminals than those of higher voltage, and as lightning is the same value in every case, the low voltage switch is more liable to go down than one of higher voltage. Pole type oil switches are now made with porcelain barriers between poles and porcelain tubes over the terminals. I do not think there is any switch even for 2200-volt service that will not stand a 50,000-voltage test when new. No factor of safety could be calculated that would be better than that.

Mr. Ward: You consider that switches as now manufactured are adequate without special protection against lightning?

Mr. Mahoney: Yes; unless the lightning is unusually severe. There are parts of the country, like Denver, where the best protection that can be obtained is none too good.

Mr. K. E. Van Kuran, Los Angeles, Cal.; Mr. Chairman, I would like to ask Mr. Mahoney what experiments have been made on the reactance type of breaker to determine whether or not this type is of assistance in eliminating surging.

Mr. Mahoney: An analysis of the design of the breaker will show that it does prevent surging. Demonstrations to verify this have also been made with the oscillograph. The fact that an ordinary oil-breaker attempts to cut the circuit open in one-half a cycle, you can readily imagine, is the worst possible condition. It endeavors to make a most complete change in the circuit conditions as rapidly as it is physically possible to make it. If you should attempt to stop a flow of water in hydraulics instantly, you know what the result would be. It is the same in an electrical circuit. If you endeavor to open a large current flow in one-half a cycle, you are trying to dissipate the complete magnetic energy or electro-static energy in the line instantly, which it is practically impossible to do. In some of the ordinary forms of oil-switch having sufficiently strong details, the first several cycles or so after the break carry an arc through the oil accompanied by considerable disturbance, and dissipate the energy in that way. In the reactance breaker the first set of contacts merely cuts in reactance. This reactance is of relatively small dimensions and is self-contained in the breaker. The mechanism of the two sets of contacts is connected positively together, so that they follow one another in definite sequence, just as rapidly as we can make them. However, there are at least two cycles interposed between the operation of one set of contacts and the other, permitting the line to equalize its changed condition through the reactance. The surge that may have started, which is relatively small, due to the circuit not being opened completely, dissipates itself in the resistance of the line, the resistance of the reactance coil and the reactance of the coil. This holds down the surging, so that when the final break occurs, a few cycles later, it has not only reduced the possibility of surges but absorbed them. The next change, as opening the second or

final set of contacts, is a relatively small one, because of breaking a much smaller current, making a much smaller change in the condition of the circuit than with an ordinary oil circuit breaker. It stands to reason that you can make a large change from a maximum to a small value without opening the circuit, and still make a very small change in the circuit conditions.

THE CHAIRMAN: If there be no further discussion we will pass on to the next paper entitled Transmission Line Construction, prepared by Mr. R. D. Coombs, of New York City.

TRANSMISSION LINE CONSTRUCTION

The very rapid increase in the number as well as in the mileage of electric power transmission lines together with the fact that practically all of the national engineering associations interested therein have agreed upon a standard specification governing the construction of such lines at the points where a foreign interest exists, *i. e.,* at the crossings, has done much to spread an intelligent interest in line construction. However, as is usual in a growing industry, no standard has been universally accepted. Further, it is not possible for any one specification or standard of construction to be universally applicable, unless such a standard has some elasticity and is interpreted and enforced with intelligence. It is within the bounds of probability that the framers of any national specification would welcome discussion and data tending either to prove the advisability of the adopted standard or to show wherein it might be revised or extended. Each of our accepted construction specifications has been the result, first, of earnest analysis of the methods current up to the date of the issue of such specification, and, thereafter, of the revision or addition of requirements based upon practical experience and growth of the art. It has also been true that many of the commonly accepted types or methods of construction and many of the requirements of a general specification have been subject to criticism. Such criticism, while honest, does not always take into consideration the varying conditions under which the engineers of a continent must work, nor the fact that the financial and executive side of any problem must be given great weight in its analysis. We are all too prone to regard our own pet method as the only good method, whereas the fact is, that construction methods may vary widely and often no one may determine which of two installations has the greater value. However, the engineers interested in transmission line construction should now be able to determine more definitely which details have become obsolete and which new methods are worthy of wider adoption.

In any attempt at standardization, either for one operating company or in a national specification, it is very necessary to weigh carefully the result both in cost and in operation, of the

adoption of any general mechanical requirement. An assumption appearing innocent and harmless may become a very serious matter if applied to all future construction, through the too common practise of copying or compiling specifications.

Location and Clearances

It is doubtful whether engineers and executives realize the extent to which undesirable construction is installed, due to inadequate efforts to obtain the necessary concessions on the part of outside interests. Isolated trees, of perhaps no particular value, have compelled the use of high poles or the unnecessary grading up of pole lines. Without wishing to appear an advocate of some of the common methods of "tree trimming," the writer believes that one large scraggly tree, more or less decayed, remaining along a curb line where the other trees are of recent regular growth, should not be allowed to interfere with the proper location of all the wires in that street.

Everywhere throughout the country, there are towns in which the telephone, lighting and power lines occupy all sorts of zones, gradually getting higher and higher, until the latest line is driven to pole heights extremely difficult to obtain. It will also be found that many telephone lines have overbuilt the present power wires and occupy the zone which should be used by future power wires of higher voltage. Whatever their attitude in the past, it is probable that the telephone and telegraph companies will now be very willing to lower their lines into their proper location, *i. e.*, that nearest the ground. It will be to the advantage of any power company to confer with the telephone or low voltage interests and arrange, by whatever mutual concessions are advisable, to shift the various lines into their proper relative positions, with the highest voltages on top.

The elimination of unnecessary poles is a matter which is not receiving sufficient attention. Three of four pole lines along the same street are a relic of the barbarous days of a certain type of competition, and have now little excuse either in politics or economics. Two examples occur to the writer which may be worth repetition. In one, the local manager of the electric company photographed the old pole lines in his town and then removed every unnecessary pole except those controlled by another and unfriendly interest. After photographing the streets anew, his

company was in a position to acquire considerable merit from the city authorities, not excluding the fire chief. In the second case, the writer's company having to construct a steel pole line through a thriving little town, found the only vacant zone for the wires was from 60 to 70 feet above the street. After a conference with the various interests, except the tree owners, it was decided to remodel the lines in that town, at least along certain streets, and to place them all in their proper zones. As a result two or three trees, semi-decayed relics of an earlier day, were either trimmed to conform with the rest of the trees in that street or cut down. Some four or five telephone lines were lowered from a height of 40 or 50 feet to a zone about 28 feet above the street, and the electric light lines placed in a zone about 35 feet above the street, enabling the new high-tension wires to be placed about 45 feet up instead of 60 to 70 feet as originally thought necessary.

It is far better to lower existing wires than to raise the new line above its theoretical zone. The stress upon the poles increases in direct proportion to the height, and in addition the higher poles do not receive the same relative protection from the wind.

The height of the wires above the ground need not remain the same throughout a long line in country which is partly barren and hilly and partly agricultural. There would seem to be little reason to provide clearance for a hay wagon on some hillside locations.

Loading

The Joint Report specifications for crossings require a figured loading of ½ in. thickness of ice + 8 lb. per sq. ft. wind pressure on the ice-covered diameter of wires. This loading was considered by the framers of the specification as generally reasonable, and with the designated factor of safety, etc., to provide the proper construction for a crossing. It is not denied that greater thicknesses of ice than ½ in., or greater pressures of wind than 8 lb. may occur, but it is improbable that they will occur in conjunction over such areas or so frequently as to make it desirable to impose a greater loading upon all future work. All the spans in a given line would never be subjected to the maximum figured load, nor would a number of adjacent short spans,

or one very long span, be likely to receive the maximum load over every lineal foot. It is true that telephone lines fail every winter, and perhaps that some old or incorrectly built low voltage lines occasionally fall, but the writer, at least, has yet to learn of the failure of a wire strung, even approximately, up to the Joint Report requirements. Further, it should be remembered that the loading and the factor of safety in question—and these factors must be considered in conjunction—were recommended for crossings and for crossings only. They have not as yet been recommended by any authoritative body for general intermediate line construction.

Before a standard loading for general line construction can be adopted, it is necessary to study the effect upon the design, of the loading, the factor of safety and any requirement as to broken wires.

Assuming that a crossing is, at least in the estimation of the company crossed, more important than an ordinary span, the next question is how much may be spent to minimize failure in any other span. Bridges and buildings are not designed to withstand tornadoes, nor need power wires be absolutely immune from failure. It is, however, becoming more and more important to provide continuity of service and to establish a standard which will satisfy all conflicting interests without unduly burdening a great industry.

The writer believes that no consideration need be given accidental loads due to falling objects such as trees, etc., and that a single ice and wind load will very satisfactorily apply in nearly every part of this country. It is true that in certain localities either a smaller or a larger loading may be justifiable, and that some installations may warrant greater security than others, but these are questions of engineering judgment and should not influence general construction.

The assumed load upon the wires should be as nearly as possible equal to the maximum loading that may be expected upon some indeterminate number of spans at some indeterminate interval of time. One or more spans in a given line may conceivably, and properly, receive a greater loading during their lifetime. Such excess loads, may, or may not, be rendered harmless by the factor of safety. A large factor of safety will undoubtedly continue to protect inaccurate assumptions of loading,

but unreasonable loads and impossible stresses do not establish wise engineering standards. If the factor of safety will eliminate nearly all the failures due to the ordinary faults of manipulation, either in manufacture or in the field, and provide for a reasonable variation in the assumed load and for such deterioration as may be expected in the material, it has served its purpose. Any decrease in such a factor may be dangerous but any increase will certainly be extravagant.

In determining upon a proper wire loading and the factor of safety to be used, it is important to bear in mind the effect of any further requirement such as a provision for dead-ending or carrying broken wires, inasmuch as the effect of the latter requirement is to impose from 5 to 40 times the former loading upon the insulator connections and the supporting structures. Dead-ending and corner turning are different only in degree, and designing for a broken wire load is more or less equivalent to designing all structures as corner structures.

It has sometimes been specified that the thickness of sleet should be a factor of the diameter of the wire—an assumption which is not borne out by the facts. Indeed the effect of the sleet load is far greater upon small wires, owing to the relative amount of surface which the ice presents to the wind. In that view at least a diameter factor would have to be reversed, thus making the whole contention rather ridiculous. Again, some specifications have provided for a load of 1/4 in. of ice + 8 lb. per sq. ft. wind pressure with a stress limit of 9/10 of the elastic limit of the wire, while at least one crossing specification contains the severe requirement of 1/2 in. of ice + 20 lb. per sq. ft. wind pressure with a stress limit of 4/10 of the ultimate strength of the wire. In order to more clearly indicate the relative effect of various loadings the approximate curves in Fig. 1, have been prepared to show the normal sag. (60 deg. fahr., unloaded) of a No. 1, B. & S., H. D. stranded copper wire corresponding to:

(1)....1/2	in. ice +	20.0	lb. wind	(120, mi. p. hr.)	max. stress,	4/10 ultimate,	= 1580 lb.
(2)....1	" "	2.8	" "	(40, " " ")	" "	1/2 "	= 1980 "
(3)....1/2	" "	8.0	" "	(70, " " ")	" "	1/2 "	= 1980 "
(4)....1/2	" "	8.0	" "	(70, " " ")	" "	6/10 "	= 2370 "
(5)....1/4	" "	8.0	" "	(70, " " ")	" "	9/10 elastic	= 2110 "

Fig. 2 is a graphical representation of the relative effect of what is termed balanced transverse loading and a broken wire condition. The ordinates are the ratios of one broken wire to one double span unbroken. In other words, the ordinates show how many times more severe a broken wire condition is than

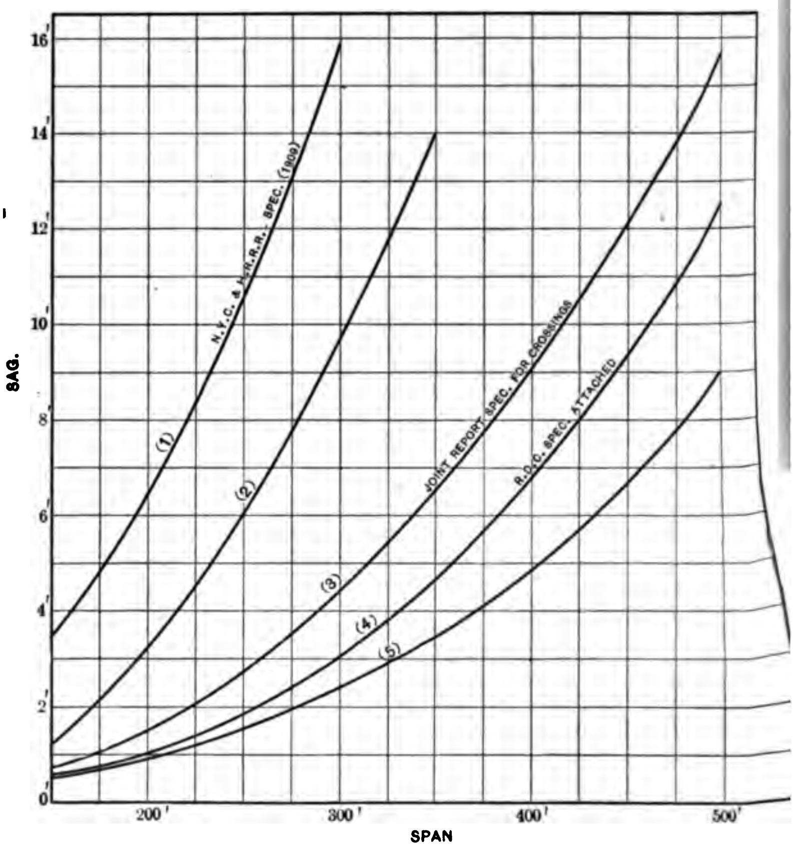

FIG. I

the same wire unbroken under identical ice and wind loads. For instance, a No. 1 hard-drawn stranded copper wire in spans of 200 feet, would, for a broken wire condition, impose 16 times as much stress upon its support as it would under balanced

loading. In determining upon a mechanical factor of safety for any material it is customary, whether so stated or not, to assume certain portions of the factor as safeguarding each of the possible elements of danger, such as errors of design, workmanship,

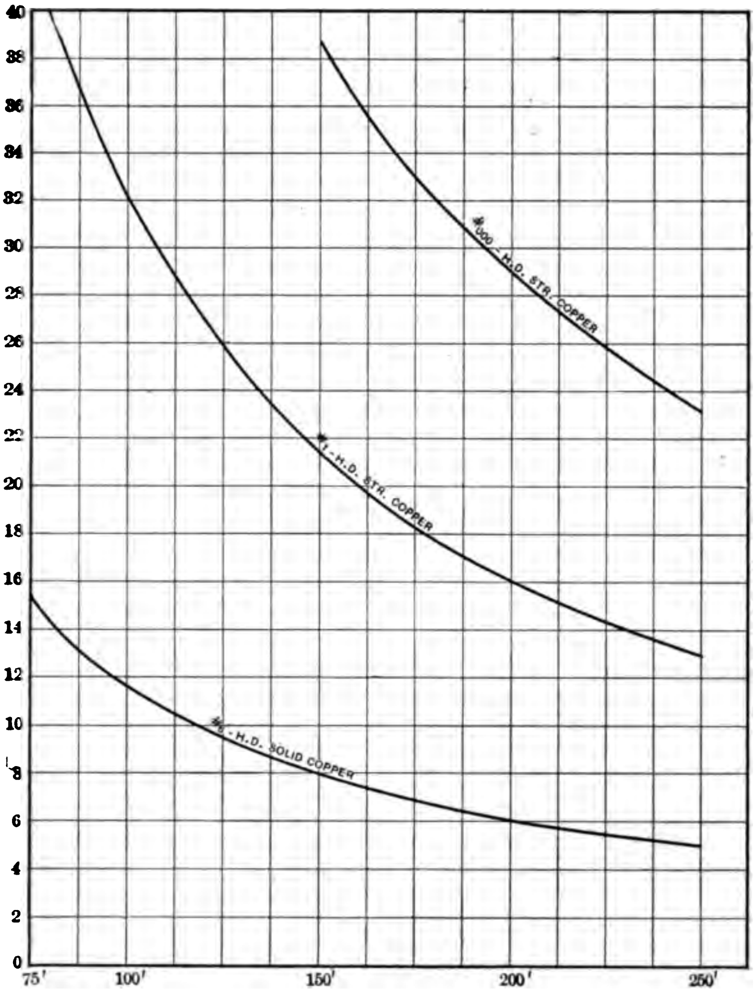

Fig. 2

excess loads and deterioration of material. In the case of wire cables, a relatively low factor may be assumed, since the material of a wire catenary, both as material and as a structural mem-

ber, is more uniform in section, strength and elasticity, and less influenced by eccentric loads or errors of workmanship, than any other engineering structure. Failure in the wires may therefore be considered as usually confined to electrical failures, i. e., those due to arcs out in the span or at the insulators. Assuming the provision of adequate clearance and proper spacing of wires in the span, the majority of wire troubles should occur at the insulators. Further, and in view of the small number of failures per insulator in the existing installations, it would seem that the increasing tendency to improve the insulation should have some effect in lowering the number of broken wires per support.

In consideration of the above it is, to the writer's mind at least, utterly indefensible to assume a severe broken wire condition in designing all poles and towers. Particularly is this true if future construction is to be in actual instead of fancied accordance with the specifications. There can be no engineering justification for a specification which premises a large proportion of wires broken under full load, when the attachments of the wires, as installed, would not withstand any considerable part of such load. Again it is probably a fact that many of the structures in existing lines are not as strong as the original test structure. This may be due to a variety of causes, such as local injury or incipient bends in light sections, lack of rigidity in the foundations, weakness against torsion, and last but not least, to the usual difference between a test specimen and the least perfect field product.

In working backward from the results of practical experience over large areas, the tendency is to overestimate both the actual loading and the strength of the structures. In other words, many existing lines, particularly the heavy wooden pole lines, remain in service not because they have a strength equivalent to some recent requirements but simply because they have never been subjected to such loads. Therefore if a severe mechanical requirement is placed in a standard specification it must be assumed that designers will eventually be driven to a literal compliance therewith, and the net result will not be equivalent to the designs of the transition period upon which the requirement is supposed to be founded. The writer is no advocate of shoddy construction, and wishes merely to emphasize the importance of a clear understanding of what is actually to be accomplished and

to remove the temptation to indulge in mental reservations in the presence of an impracticable requirement.

Foundations

The proper penetration of wooden poles is the result of many years of actual experience under the varying conditions of different soils. It is not a matter which may be determined accurately and readily by a mathematical formula. In an ideal formula there must be a variable "constant," the value of which depends upon the particular soil in question. Inasmuch as it is impracticable to make advance tests of the soil conditions on a long transmission line, it is necessary either to have two standards or to design a single foundation which will provide safely for ordinary variations in the soil.

In an attempt to reduce the cost of the original installation a number of lines have been built with weak foundations. Some of these supports have already failed and the length of service of others is a matter of conjecture. It is true that the foundation cost in wide base structures may be comparatively high, but the insurance value of a good foundation is well worth its cost. The use of shallow foundations is doubtless due in a measure to the methods in vogue in testing towers. A test tower on a concrete or metal foundation not only gives no information in regard to the subsequent foundation, but includes a false sense of security both in the probable action of the foundation, and in the tower itself.

The foundation has in fact two functions, first, to prevent uplift, and second, to provide against buckling at the point of maximum leverage; and a foundation member or ground stub which is not firmly supported against horizontal movement at the ground line may introduce stresses not contemplated by the designer. A test tower upon a rigid foundation will give higher test values than the line towers in actual service, and the test is therefore deceptive by the amount representing the effect of this rigidity. In structures in which the main legs are unsupported for relatively large values of $\frac{l}{r}$, or in which the tower itself has much less strength in one direction than in the other, a rigid anchorage is necessary to provide the conditions assumed in the design. In some soils certain pole and tower designs have a strength in excess of that of the foundation against overturn-

ing, the result being that the weakest feature of the line is not even suspected by the line department until failure occurs. There are no pole penetrations of less than 5 ft. in the standard pole settings for wooden poles, but metal structures have been designed with penetrations of 3 ft. 6 in., which is not as deep as the ordinary frost line.

The protection of the metal in the anchorage, is naturally of vital importance to the permanence of the structure. If there are some localities in which galvanizing is no real protection there are also places where galvanizing is more economical than paint. If the anchorage is encased in concrete, the encased portion may safely be considered as having a longer life than the superstructure. The point of entrance of the metal into the concrete is usually considered to be the location of the future maximum corrosion, whether the structure is painted or galvanized. The writer believes that this assumption is not always correct, and that the location of future deterioration will depend upon the relative effect of acids, etc., carried by air currents to the upper portions of the structure, versus the amount of dirt and water at the base. However, there can be no question of the propriety of ground metal protection, and data upon the results obtained by galvanizing, concrete, asphalt, tar, treated burlap, additional coats of paint, etc., are needed. In spite of the claims for various less-corrodible steels, there does not seem to be any extended use of such metal in bridge work, where it would be an economy if practicable, so that proper installation, inspection, and maintenance are as yet the only safeguards available.

Ground Wires

Admitting that the present period is one of transition from the poor mechanical construction of some older lines, there is little excuse, in theory at least, for some of the newer developments. In the light of our present knowledge a ground or sky wire seems a desirable addition to lines of 11,000 volts or more. If, however, the ground wire is of less permanent material than the power wires under it, or improperly connected to the supports, it becomes a menace rather than a safeguard. It is hardly imaginable that a poorly constructed ground wire will not, at some future day, put the line below out of service.

The relative merits of galvanized steel, galvanized iron, copper-covered or copper wire are perhaps not definitely fixed for all

conditions, but the writer ventures the assertion that the questi is worthy of much more careful consideration than it has thus far received. If a long, smooth, well-rounded wire seat in the clamps is a wise provision for the attachment of the power wires, why in the name of common sense is it not equally desirable in the ground wire which over builds the power wires?

It is a matter of common knowledge that a short rigid metallic connection with a small U or hook bolt biting into the wire has a tendency to cause wire failure. Why then does anyone install such a connection in the very worst possible place on a power line?

The ground wire connection differs from the power connections in that it is usually treated as a dead-end connection at every pole or tower. A variation in sag due to the accidental or intentional slip of a power wire has less opportunity to make trouble than a similar slip in the ground wire. In the case of the so-called flexible towers—by which is meant those having little theoretical strength in the direction of the line—a firmly attached ground wire is needed to serve as a partial guy to help minimize the extent of tower failure. The ground wire attachment will therefore usually be well tightened, whatever may be the fact in the power wire attachments. If then the small rigid power wire clamps have been the cause of line wire failure, is it not extremely probable that similar connections will eventually develop ground wire failures?

On certain types of supporting structures the ground wire is connected to a vertical earth wire leading to a ground plate beneath the support. This connection should be arranged to preserve, as much as possible, the original strength of the ground wire. The "down" attachment is necessarily at the point of maximum mechanical stress in the ground wire, and therefore soldered or bent connections are particularly undesirable.

Grounded Arms

The relative cost of maintenance *versus* the insulating qualities of wooden and metal cross-arms is still an open question. For the higher voltages the metal arm is now more common and is probably preferable, the debatable ground being for voltages between 5000 and 20,000 volts. Within these limits it is believed that the operating department will usually favor wooden arms,

although the maintenance of the arms alone may be higher than with metal arms. The matter is further complicated by the requirements for grounding and holding power wires in case of insulator or wire failure at crossings. The advocates of metal arms and a ground strip, ground arm, or arcing cap must, in order to prove the efficiency of the device, assume that the insulators will need no help from the insulating value of the arm, and that the wires falling from a shattered insulator can in some manner be prevented from leaving the support.

In some cases an auxiliary or second attachment of the power wire is used, but unfortunately this is not always as effective as it appears. For instance, if such an arrangement contemplates the use of a dead-end connection on a pin insulator, it is in itself undesirable, and mechanically impracticable for heavy stresses. It has also been proposed that the wire be protected from arcs by the use of an arcing strip, cap, etc., but this is not literally effective if a shattered insulator will allow the attachment and the wire to fall. Again, it is not always possible by the use of any device at the support to prevent a wire broken out in a span from coming in contact with a line beneath it. However, as the great majority of failures should occur at the insulators, it would seem wise to neglect this possibility and concentrate attention upon other features of the connection at the supports.

In the writer's opinion too little value has been attached to the ability of a wire to hold, over a doubled span length, in case of pole failure. For the ordinary short span construction and reasonably low voltages there is little reason to doubt that the wire will at least be less liable to injury if there is no grounded arm. Therefore any grounding device should include provision to minimize any actual separation of the wire into two spans, either of which may fall.

The introduction of a grounded arm is also vehemently opposed by those responsible for the safety of line-men who work on live wires. The limiting voltage of such work is not constant throughout all climates, and if wooden poles are used it is unquestionably a hazard to ground the arms.

Supports

The poles or towers used up to the present time have been of wood, steel and reinforced concrete and they have been used in the

order given, both as to numbers and priority of installation. The wooden pole, still the most common form of support, particularly for low-voltage lines, has several objectionable features in that it deteriorates rather rapidly, is subject to fire, and its cost is increasing. Under certain conditions the wooden pole is, however, still economically sound construction even for high-tension lines, although the time is not far distant when it will be no longer good practise for a first-class installation.

In changing from wood to metal, however, we may profitably pause to consider some of the characteristics of the structure which have rendered possible our progress in line construction. In theory as well as in fact the wooden pole is a precedent for the metal structure, and a too violent divergence from some of its good features may result in structures not relatively as excellent as the wood they replace. A well-selected timber pole is very nearly of the ideal outline, due to the fact that the stresses imposed upon it in its original life were almost identical in nature with those in pole line service. It should not be forgotten that a wooden pole has equal strength in all directions, both with and across the line, and a comparatively large strength in torsion. These qualities tend to minimize the effect of accidental loads or loads other than those assumed in design. Again, the wooden pole has considerable elasticity but not complete flexibility, a characteristic which enables it to deflect enough to equalize most unbalanced loadings while opposing a very considerable restraining force against the spread of failures along the line. This semi-flexible feature of a wooden pole, which is also obtainable in steel or reinforced concrete, is probably of much greater advantage than is generally realized. The final general characteristic of the wooden pole is that it is not easily injured in handling, and requires very little intelligence to install. There are no long thin sections which may be bent and rendered useless and no considerable number of flimsy connections in the make-up of a wooden pole. That the above good qualities have been largely instrumental in securing the excellent record of wooden poles in line work cannot be doubted by the analyst, and their lesson is well worth attention.

The more permanent types of support may be divided into the rigid wide base steel tower, the semi-flexible pole, either of steel or reinforced concrete, and the flexible steel pole or frame. Apart

from their relative cost for any given line, there is to be considered the ultimate adaptability of the type. This adaptability will involve the questions of protective coatings, of rights of way, of freedom from serious interruptions to service, and finally, and to the writer's mind of very considerable importance, of the relative prominence given the installation.

Under favorable climatic conditions, particularly over rough unsettled country where all maintenance operations are expensive, galvanizing is thought to be more economical than painting, at least for wide base towers. In the more compact structures the cost of painting is reduced owing to the ease with which a painter can move about. No very definite knowledge exists as to the regions in which galvanizing does not afford proper protection, although it is generally assumed as being unsatisfactory in the neighborhood of coke ovens, smelters, steam plants, etc., and near the seacoast. It may also be true that certain soils, such as swamps, induce rapid deterioration. It should be noted that the use of sections ⅛ in. in thickness presupposes that their protection by galvanizing will be absolutely effective. The galvanizing of structural members—by the hot process—can be done in a very uniform manner and in strict accordance with the standard requirement, even though the real efficiency of the average inspection is open to question. The standard test is an accelerated specimen test, and although the only practicable one, is subject to the usual criticisms of such tests.

In painted structures the careless application of paint and the use of inferior grades of paint cannot be too strongly condemned. Although paints vary in price from about 40 cents to $1.40 per gal., the possible saving is small compared with the risk of deterioration. The usual requirements for painting are few in number and impossible of misinterpretation, but unfortunately they are more honored in the breach than in the observance. It seems necessary therefore that the executive department insist upon proper inspection and maintenance, as the mere insertion of the usual clauses in a specification has, as yet, failed to produce the contemplated result.

In the progress of a rapidly growing industry there is always a tendency to apply methods of work to sections of the country to which they are less adapted than the locality of their previous successful use. To the writer's mind the adoption of the so-

called wind-mill tower in the more densely populated and more severe climatic conditions of the East, may not be judicious. In such regions, there are two considerations other than cost, *i. e.*, the undue prominence of the line and the great importance of failures. The wind-mill tower is rather noticeable, but it provides a type of support with which failures are practically confined to one span. The flexible frame is not so noticeable, but it has little or no strength in one direction and will therefore presumably be subjected to a more severe type of failure. The semi-flexible pole or tower, occupying a position about midway between the two types of structure mentioned, has at least a theoretical advantage over either. While some flexibility is useful in a narrow base structure, in order to permit "pull back" from adjoining span wires, the amount of the movement of the pole top need not be excessive. In actual service heretofore this movement cannot have been very great, for the simple reason that the commonly used attachments have not sufficient strength to develop such unbalanced wire tensions. The desideratum is perhaps a certain elasticity rather than extreme flexibility. In fact, a reasonable bending or semi-flexibility is obtainable even in reinforced concrete.

In sparsely settled country or where the right of way is for any reason not accessible or not subject to cultivation, the spread of tower bases is unimportant. If more than one high-voltage line will be placed upon a private right of way, the separation of the lines will usually depend upon factors other than the spread of the bases. When land is more valuable the wide-base tower may be impracticable. For instance, there will probably be many power lines placed upon the rights of way of the interurban electric lines. The development is natural and necessary, but railroad rights of way do not provide space for wide-base construction.

The wide-base tower and the semi-flexible pole should, when properly designed, provide the maximum security against interruptions to service caused by insulator or wire failure. The greater strengths possible in such structures allow the use of longer spans, with a consequent reduction in the number of insulators, and the probabilities of insulator failure are thereby lessened. In case of wire failure, whether due primarily to insulator failure or not, the spread of such failure along the line is

arrested before it has influenced more than a span or two. The remaining factor of adaptability, *i. e.,* the relative prominence of the various structures in the landscape may prove of considerable subsequent importance. The writer does not mean to imply that a transmission line may be made decorative, but rather that it be made inconspicuous. Even in regard to decorative effect, it is not absolutely necessary that it be an ungainly blot upon the landscape. Some regard to pleasing outlines is not amiss, and it is a well-known structural fact that a graceful design is usually economical. If lines situated in settled communities are to remain undisturbed for any considerable period of time hereafter, they will have to be either unobjectionable in performance or invisible.

The design of steel or reinforced-concrete poles and towers is fortunately becoming less hampered by demands for excessive cheapness, and the regulations current in other structural work are no longer entirely disregarded. The wisdom of this should be apparent when it is considered that a few hundreds or thousands of dollars "saved" on the line construction may jeopardize the efficiency of an investment of millions of dollars. It is true that thus far existing construction has given fairly satisfactory service, but it is equally true that the more extended use of faulty designs would eventually bring disrepute upon the industry and through failures invite the enforcement of severe regulations by various authorities.

In any type of support the importance of eliminating long unsupported members and of providing a firm rigid base is now becoming more generally recognized. In poles and towers as in any other kind of construction, a poor foundation results in a poor superstructure, and it is probable that there have been more actual tower failures due to or superinduced by faulty foundation design than from any other cause.

There has been a very general elimination of the rod bracing with faulty end connections, inherited from the old wind-mill practise. For years the rule in other classes of structural work has been to require rod bracing to be made adjustable, usually by means of right and left threads.

A long slender member is not well adapted to take compression and it has been customary in other work to limit the relation of the length to the radius of gyration. In transmission line construction very much higher values of this ratio have been

used than are generally permitted. It is probably not necessary to adhere to the low limits of building construction, but it is equally probable that too much latitude has been taken in some cases heretofore. The writer recalls the rather incredulous air with which some members of another engineering society received his statement that ratios of $\frac{l}{r}$ of 200 to 300 had been used in tower work.

Admitting that there is a difference in the kind of service or, in all events, in the number of applications of the load, between tower and building work, there is a very marked variation in the attitude toward bolted connections in the two types of construction. In building work single bolts are discouraged or if used, low strength values are allowed. In tower work all connections are bolted, and the majority are one-bolt connections in which no reduction of value is assumed.

Theoretically a one-bolt connection should be further reduced as the full strength of the connected member is not available—this is never so assumed in tower work. Again, the bearing of a bolt is assumed as being upon a surface as thick as the member; in fact, the bearing will be only upon a line.

The use of cast iron or malleable iron has been almost eliminated from general structural work, and similar progress is now being made in poles and towers. The more recent designs of transmission line supports do not employ any castings in the main structure, although they are properly applicable to the wire connections. Similar reasoning should prohibit the use of castings in the working parts of reinforced concrete poles, such as in hoops or bands.

In conclusion and in order to promote a discussion upon proper line construction particularly for voltages in excess of 6600 volts, the writer hopes to present informally his views on desirable detail requirements. (Mr. Coombs had with him a draft specification.)

DISCUSSION

MR. ERIC A. LOF, Schenectady, N. Y.: I shall not attempt to discuss this paper in detail, but I would like to call to your attention some quite serious interruptions that have occurred during the past winter in connection with transmission lines

having suspension insulators, troubles which must be considered in designing new lines. They are caused by the formation of sleet on the wire. The sleet falls off the alternate wires, but remains on the middle wire, we will say, so that this wire sags down and touches the other, causing a short circuit. The lines affected have usually been those using double circuits with the wires suspended vertically below each other, and, of course, the only way to remedy the difficulty would be to increase the spacing, or, as some companies are doing now, increase the length of the middle arm so that the wires do not swing below each other. Some very important new lines have been designed that way.

Another source of trouble that has developed has been with the connections of aluminum lines. The wind lifts both the wires and the insulators, and as in some cases the insulators are raised quite close up to the crossarms, there is danger of the wires touching the crossarms. That has been overcome, in one case I know of, by placing weights underneath the insulators, so as to make the string rather heavy.

Another thing which must be looked out for is that the sleet may fall off one span, which, of course, throws an addition strain on the tower.

MR. F. B. H. PAINE, Buffalo, N. Y.: It is very gratifying to find a structural engineer, who is competent in other lines of work, willing to throw aside some of his previously conceived ideas and adapt structural designs to the requirements of line construction. It is not a common occurrence.

One most important value in Mr. Coombs' paper is his urging of good construction. I have not had an opportunity to go over it in detail, or over the specifications to which he has referred. They are, I know, however, from an acquaintance with his methods, representative of good construction, not the only way to do it, but a good way to do it. It does not cost any more in the beginning to do work right than it does to do it almost right. The saving in reconstruction and maintenance will over-weigh any possible temporary economy obtained by slighting mechanical strength. The inspection of transmission lines, particularly across country, is very hard to do properly, and maintenance is a matter of some difficulty, so that good construction is well worth while.

Mr. A. N. Richardson, Kansas City, Mo.: We rebuilt a number of our 66,000-volt crossings recently, and immediately had trouble with their burning down during lightning storms. We concluded it was due to the wooden cross-arms used in the construction. We attributed it to the fact that that was the point of least insulation on the line, and concluding that we should have more insulation at that point, we placed insulators on these crossings where we had standardized according to specifications with a larger factor of safety. We feel that our experience proves quite conclusively that on a wooden pole line with wooden cross-arms you have your weakest point right at the spot where your intentions are to have it safest.

Mr. C. P. Osborne, Portland, Ore.: I was very much interested in Mr. Coombs' paper. In Oregon, we have, perhaps, conditions different from what you have in the East, inasmuch as we are troubled more or less with sleet storms. Two years ago on a 60,000-volt wooden pole line about 30 miles long, one storm covered about nine miles with four-and-an-eighth inches of sleet, solid ice. That was measured by myself four times in different places, so I am sure I am right. It is needless to say the line went down.

We have a right-of-way 100 feet wide, and on that right-of-way we have four lines, one 33-cycle, 30,000-volt, and three 60-cycle, 60,000 volt. Of course, you may say it is not sound electrical construction to have so many lines on a 100-foot right-of-way, as it makes the separation rather small. In some oscillograph records which we have taken, while our tests were made on the 60-cycle, yet you can see the 33-cycle tests. Dr. Steinmetz, of the General Electric Co., now has these records, and he is making us a report on the trouble we are having with the suspension type of Ohio Brass Co. insulators. We are, I believe, the only people in the world that have failed. It is really a sore spot with us. We have spent a quarter of a million dollars on a power line which we expected to be absolutely reliable. Our pole line has not given any trouble, but we have punctures, not flash-overs, on the suspension type of insulators.

A question comes up in my mind, and I seem to have been about the only one in the country who has thought of it, whether a very large wireless station, about six miles from Portland, could

affect us. It is set in a hollow, with hills all around it, and is about 300 miles from our power house. The surges we get in that line at times are enormous, and the eight break-downs that we have had on it certainly, to use an old expression, have got our goat.

MR. PAYNE: You have punctures in your suspension insulators when they are set in the strain position?

MR. OSBORNE: The punctures are all over the line.

MR. PAINE: But do you ever find them in the suspended insulators?

MR. OSBORNE: They are in the suspended insulators. Three of the punctures have been where the insulators hung straight down. Four of them have been on curves; one of them was on a dead end. We are very much interested in finding out why we have trouble when nobody else does.

MR. PAINE: There is plenty of trouble with all makes of suspension insulators used in strain, and apparently the experiments to which Mr. Austin referred yesterday show that it was because of their elastic limit, if I may use that expression in regard to porcelain; but I am surprised to hear of it in a suspended insulator.

MR. OSBORNE: Mr. Austin spent a month with us and he found that the trouble was not caused by mechanical overstrain of the insulators.

MR. PAINE: How can you be sure of that?

MR. OSBORNE: That is something he went into very thoroughly. Of course, we only had his word for it. He said that we had not overstrained the insulators mechanically in the sleet storm.

MR. COOMBS: Had the insulators which failed been subjected even in a suspension position to a very heavy sleet load? I will admit that in a vertical position the mechanical load is not very great, it is well within the strength of the insulators which is probably about 9000 pounds. However, I believe the whole matter is one of the fatigue of material and I wonder what those particular insulators had gone through in the way of a very heavy or a comparatively heavy mechanical load.

MR. OSBORNE: I will say this, that the first three punctures we had came before any sleet storm had occurred. This is something that we are really very much worried about, I assure

Technical Sessions

TECHNICAL SESSIONS

FIRST TECHNICAL SESSION—JUNE 3, 2.30 P. M.

1—Report of the Committee on Meters. W. H. FELLOWS. (With Third Edition of Code for Electricity Meters)

2—Report of Committee on Grounding Secondaries. W. H. BLOOD, JR.

3—Report of Lamp Committee. FRANK W. SMITH

4—Paper: *"Recent Progress in the Art of Lamp Making."* J. E. RANDALL AND E. J. EDWARDS

5—Paper: *"The Relation of the Incandescent Lamp to Lighting Service."* M. D. COOPER AND R. E. CAMPBELL

6—Report of Committee on Measurements and Values. A. E. KENNELLY

SECOND TECHNICAL SESSION—JUNE 5, 10 A. M.

1—Report of Committee on Prime Movers. I. E. MOULTROP

2—Report of Committee on Electrical Apparatus. L. L. ELDEN

3—Report of Joint Committee on Overhead Line Construction. FARLEY OSGOOD

4—Paper: *"Switchboard Instruments."* PAUL MACGAHAN

5—Paper: *"The Latest Developments in Distributing Transformers."* E. G. REED

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THIRD TECHNICAL SESSION—JUNE 6, 2.30 P. M.

1—Report of Committee on Underground Construction. W.] ABBOTT

2—Paper: *"Transformers for Power Transmission."* H.] RUDD

3—Paper: *"Electric Railway Loads on Central Stations."* E. DILLON

4—Paper: *"Late Developments in the Flame Carbon Arc Lamp* W. A. DARRAH

5—Paper: *"Overhead Distribution Circuits for Series Arc Ligh ing."* T. K. STEVENSON

6—Paper: *"Switching Apparatus for Rural Installations."* E. MERRIAM

FIRST TECHNICAL SESSION

TUESDAY AFTERNOON, JUNE 3

THE CHAIRMAN, VICE-PRESIDENT J. B. McCALL: Will you please come to order, gentlemen. The first business of the meeting is the Report of the Meter Committee. I would like to make just one little announcement beforehand so that it will be understood. We have the Report of the Lamp Committee and two papers on Incandescent Lamps, and in order to save as much time as possible, it is my thought to have those papers read before any discussion is had, as they are on a kindred subject. I will have you bear that in mind, so that when we come to the point of discussion, you will understand it. I will call upon Mr. W. H. Fellows, of Washington, Chairman of the Committee.

REPORT OF THE COMMITTEE ON METERS

INTRODUCTION

Since early in the year 1910, your Committees have been working with the Meter Committee of the Association of Edison Illuminating Companies, formulating a code for electricity meters. Last year this code was revised and completed by the joint committees, and it is now presented in its latest form, as a part of this report. It has proved to be an invaluable guide to Public Service Commissions in formulating rules for electricity meter practise as well as to member companies. That the establishment and operation of Public Service Commissions is an active topic is indicated by the citation of new and revised laws and rules bearing on this subject.

The Electrical Meterman's Handbook, published last year, has filled a long felt want, and no members of the meter department, or of any other branch in a public utility organization can afford to be without a copy of this valuable book. It has been valuable also in establishing standards which have indicated to Public Service Commissions what is best practise in the measurement of electricity. Having in mind the revision of this handbook at some future time, information has been gathered from which subject matter may be taken for the handbook. An immediate revision is not contemplated, however.

Last year the Committee on Meters had before it for consideration a standard form of dial face for watt-hour meters, and a form has now been approved by your present Committee, and the Meter Committee of the Association of Edison Illuminating Companies. A letter signed by the chairmen of the committees of both associations, giving specifications for and a cut of this standard dial face, was sent to the different manufacturers, and the co-operation of most of these has been assured.

The matter of metering rapidly fluctuating loads, and the standardization of meter and instrument connections when used with instrument transformers, have been both discussed and investigated by the Committee. The tentative ideas of the Committee as expressed herein, will, it is hoped, receive attention and lead to a discussion of these very important subjects.

Because of the tendency among our companies to abandon frequencies higher than 60 cycle and to change entire systems accordingly, it was considered advisable to have tests made upon induction watt-hour meters while operating upon standard frequencies other than those for which the meters were designed. Some very interesting, instructive and valuable data were obtained.

The Committee wishes to extend thanks to Messrs. E. F. Brooks, P. G. Agnew, T. T. Fitch, and C. L. Huber of the Bureau of Standards, for valuable assistance rendered.

RECOMMENDED STANDARD DIAL FACE FOR WATT-HOUR METERS

The report of last year's Committee on Meters showed the desirability of devising, for general adoption, a standard form of dial face marking, and the active Committee, jointly with the Meter Committee of the Association of Edison Illuminating Companies has resumed negotiations at the point to which they had been carried by the former Committee.

The result of the deliberation of the joint committees is presented for your consideration in the specifications given herewith and the illustration of the dial face designed.

Specifications

The standard dial face for watt-hour meters should consist of four circles as shown in the accompanying illustrations.

"The wording, to appear on the direct reading dial face, should consist of the words 'KILOWATT-HOURS' below the dials, and on registers requiring a register constant other than unity, the wording should consist of 'KILOWATT-HOURS' below the dials and 'MULTIPLY BY......' above the dials.

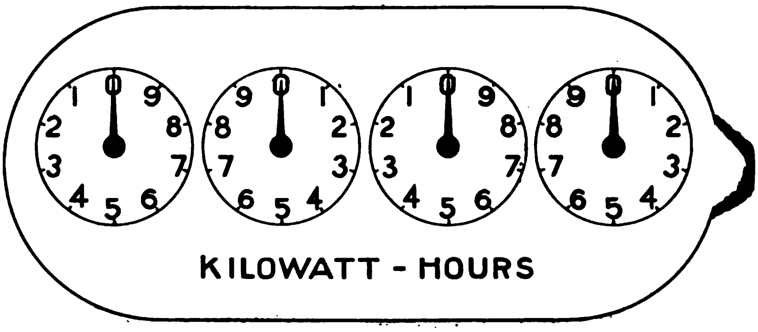
"When register constants other than unity are used, they should be ten (10) or integral powers thereof.

"The circles on the dial should have a minimum diameter of three-quarters (¾) of an inch and should have the digits zero (0) to nine (9) placed vertically as in the accompanying illustrations; no wording, other than mentioned herein, to appear on the dial face.

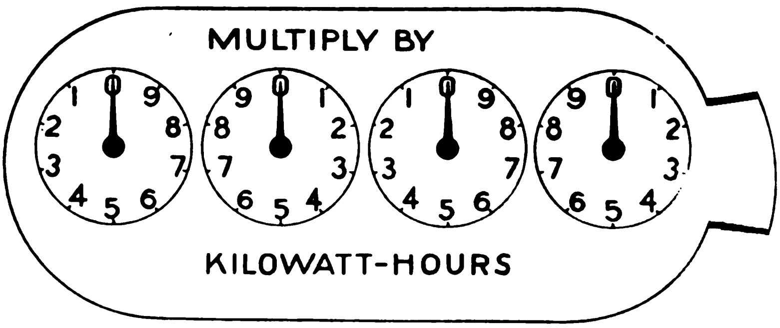
"A dull finish either in metal or porcelain enamel is to be preferred to a surface with a glaze.

"We recommend that dial faces conforming to these specifications be placed on all watt-hour meters of such types as may be made by your company in the future."

As will be seen, the Committee has secured a simple, convenient, economical and easily read design, having only the necessary features, and with no possibility of misinterpreting the values of the digits.



DIRECT READING DIAL FACE



DIAL FACE WITH REGISTER CONSTANT OTHER THAN UNITY

FIG. 1

APPROVED STANDARD MARKING FOR WATT-HOUR METER DIAL FACE

A copy of these specifications, with a proof of the dial face design has been sent to all manufacturers of electricity meters in America. The Committee reports with much satisfaction that favorable replies have been received from practically all of them.

EFFECT OF USING INDUCTION WATT-HOUR METERS ON FREQUENCIES OTHER THAN THOSE FOR WHICH THEY WERE DESIGNED

One page 399 of the Electrical Meterman's Handbook is a paragraph pertaining to change in frequency made upon a system, and its consequent effect upon accurate metering. While it is possibly not so apparent, it is nevertheless no more correct to place an induction meter on continuous current than it is to operate a 60-cycle meter on 25 cycles. In other words, large errors will result from the use of induction watt-hour meters on frequencies for which they are not designed. In some cases, however, meters are arranged for use on either of two frequencies by means of slight changes recommended by the manufacturer.

There seemed to be a lack of data on this subject and it has therefore been investigated. The Committee requested the United States Bureau of Standards to make tests upon several types of 5-ampere, 110-volt, induction watt-hour meters, the results of which follow:

A denotes 5 ampere, 110 volt, power factor unity
B denotes 5 ampere, 110 volt, power factor 0.50
C denotes 0.5 ampere, 110 volt, power factor unity

133-CYCLE METERS

		Percentage of Accuracy 133 Cycles			Percentage of Accuracy 60 Cycles			Percentage of Accuracy 25 Cycles		
Make	Type	A	B	C	A	B	C	A	B	C
Gen. Elec.	I	102	101	101	106	39	107	53	—48	50
Gen. Elec.	I10	97	96	97	116	101	116	101	53	105
Westinghouse	B	100	101	101	102	93	103	93	66	96
Westinghouse	C	100	101	100	103	95	103	95	72	97
Westinghouse	OA	99	102	101	104	98	106	92	58	97
Ft. Wayne	K	99	99	99	101	87	103	69	28	68
Ft. Wayne	K3	103	100	102	107	93	108	87	49	87
Ft. Wayne	K4	101	102	100	107	71	107	77	00	79
Sangamo	H	100	103	101	104	91	107	83	48	85
Duncan	M	100	103	99	108	72	111	60	—02	68

60-CYCLE METERS

		Percentage of Accuracy 133 Cycles			Percentage of Accuracy 60 Cycles			Percentage of Accuracy 25 Cycles		
Make	Type	A	B	C	A	B	C	A	B	C
Gen. Elec.	I	79	116	82	100	105	102	87	17	90
Gen. Elec.	I10	81	97	71	100	99	93	87	40	83
Westinghouse	B	92	109	92	97	100	99	93	69	88
Westinghouse	C	94	114	94	100	101	99	92	72	93
Westinghouse	OA	94	108	94	100	100	100	88	53	91
Ft. Wayne	K	94	118	96	101	101	101	75	40	77
Ft. Wayne	K3	92	107	91	101	100	100	87	57	86
Ft. Wayne	K4	90	108	92	100	100	101	88	66	90
Sangamo	H	94	122	94	102	103	101	80	52	80
Duncan	M	91	109	94	100	100	100	64	45	62
Columbia	C1	101	71	98	101	98	102	54	59	59

25-CYCLE METERS

Make	Type	Percentage of Accuracy 133 Cycles A	B	C	Percentage of Accuracy 60 Cycles A	B	C	Percentage of Accuracy 25 Cycles A	B	C
Gen. Elec.	I	45	105	50	81	133	80	99	101	9[illegible]
Gen. Elec.	I10	50	88	53	87	118	86	99	99	10[illegible]1
Westinghouse	C	67	138	68	94	140	91	99	100	10[illegible]1
Westinghouse	OA	66	96	67	88	106	85	100	100	10[illegible]
Ft. Wayne	K	73	107	72	94	125	96	101	103	10[illegible]5
Ft. Wayne	K3	80	92	77	91	104	89	101	101	10[illegible]2
Ft. Wayne	K4	54	99	54	87	64	84	99	101	10[illegible]
Sangamo	H	51	111	54	85	131	81	99	97	10[illegible]
Columbia	C1	132	91	140	142	122	154	100	100	10[illegible]

METER Make	Type	Frequency Cycles	LOSS IN POTENTIAL CIRCUIT—WATTS At 133 Cycles	At 60 Cycles	At 25 Cycles
Gen. Elec.	I	133	3.0	9.2	23.7
Gen. Elec.	I	60	1.1	3.7	13.8
Gen. Elec.	I	25	0.1	0.3	1.3
Gen. Elec.	I10	133	0.5	1.6	12.5
Gen. Elec.	I10	60	1.1	2.8	28.0
Gen. Elec.	I10	25	0.1	0.4	1.4
Westinghouse	B	133	0.7	1.7	5.6
Westinghouse	B	60	0.7	1.7	5.4
Westinghouse	C	133	0.8	1.5	5.0
Westinghouse	C	60	0.9	1.8	5.5
Westinghouse	C	25	0.3	0.8	1.3
Westinghouse	OA	133	0.7	1.2	9.0
Westinghouse	OA	60	0.7	1.6	11.0
Westinghouse	OA	25	0.4	0.9	2.0
Ft. Wayne	K	133	1.2	3.0	10.4
Ft. Wayne	K	60	0.9	2.1	8.2
Ft. Wayne	K	25	0.1	0.4	1.2
Ft. Wayne	K3	133	1.0	2.1	7.8
Ft. Wayne	K3	60	0.9	2.1	7.8
Ft. Wayne	K3	25	0.3	0.9	2.8
Ft. Wayne	K4	133	1.1	3.2	10.9
Ft. Wayne	K4	60	0.9	1.9	5.0
Ft. Wayne	K4	25	0.6	1.0	2.2
Sangamo	H	133	0.8	1.0	2.8
Sangamo	H	60	1.0	1.2	3.0
Sangamo	H	25	0.8	1.0	2.9
Duncan	M	133	1.0	2.8	8.4
Duncan	M	60	0.9	1.8	5.0
Columbia	C1	60	0.7	1.8	8.7
Columbia	C1	25	0.2	1.0	4.3

There was but one meter of each make, type and frequency tested. These figures should be used as a basis of comparison in this sense only, and are given as a caution to central-station companies confronted with the problem of changing their systems from one standard of frequency to another.

From an analysis of the tables it is evident that when changing a system from high to lower standard frequency, the meters should be changed first; but when changing from low to higher

standard frequency, the meters should be changed last. This will safeguard the potential circuits against undue heating or burn-outs.

In some types of meters, the test constants, gear ratios, etc., vary considerably for the different frequencies. Information of this character for 25-cycle meters is given later in the report.

METERING OF RAPIDLY FLUCTUATING LOADS

A number of questions have been raised during the past year as to the accuracy of watt-hour meters in the measurement of rapidly fluctuating loads, such as flashing signs, welding machines and loads having similar characteristics. Particular inquiries have reached the committee as to welding machines of large capacity requiring large amounts of current for extremely short periods of time; and there seems to be a well-defined feeling that the meter in such cases fails to register all the current used. This belief has undoubtedly been engendered by the small amount of revenue derived from many of these installations in proportion to the kilowatt capacity installed. Your committee feels, however, that this is not due to any inaccuracy on the part of the watt-hour meter.

The Committee has not been able to actually conduct any tests to determine the accuracy of meters measuring such loads, but from information gathered from manufacturers' tests and other investigations, there appears to be no error in the commutator type of meter under these conditions. It is claimed, however, that there is a very slight error in the induction type of meter on such loads; i. e., the meters have a tendency to register slightly more energy than that actually used. This error, is, however, so small as to be practically negligible, falling well within 1½ per cent, except in extreme cases. This error may exist in the induction type meter due to the fact that during the time the load is increasing more rapidly than the moving element can respond, flux from the current coil is present, which is a normal condition, but when the moving element is drifting after the load has been cut off, there is no flux from the current coils, and its damping effect on the moving element is absent. It is obvious, therefore, that very widely fluctuating loads can be metered well within the commercial limits of accuracy, and that the energy used by welders and other apparatus is accurately measured. The following references pertinent to this subject are submitted:

Orlich und Schulze, *Elektrotechnik und Maschinenbau*, vol. 27, p. 801, 1909. (Science Abstracts B, 1909, No. 1030.) Both theoretical and experimental.

Schmiedel, *Elektrotechnik und Maschinenbau*, vol. 29, p. 555, 1911. (Science Abstracts B, 1911, No. 671.)

L. T. Robinson, *Electrical Review* (Chicago), vol. 59, p. 1232, 1911.

Melsom & Eastland, *London Electrician*, May 17, 1912, p. 216; Editorial, p. 228. Discussion of this and another paper on the same subject by Prof. D. Robertson before the Institute of Electrical Engineers, p. 230.

INSTRUMENT TRANSFORMER CONNECTIONS

The subject presented below is deemed of sufficient importance by your Committee, to be brought forward for discussion at this time. The general notes given, are, however, merely tentative and suggestive, and will be revised after discussion and more thorough consideration. It is suggested that this subject be re-opened by future committees and furthered by conference and co-operation with others interested.

GENERAL NOTES REGARDING A PROPOSED STANDARDIZATION SYSTEM OF CONNECTIONS FOR INSTRUMENTS AND ELECTRICITY METERS USED WITH CURRENT AND VOLTAGE TRANSFORMERS

1—*Preface*

The objects sought in the suggested changes in manufacturers' connection diagrams are as follows:

(1) To secure greater clearness of the electrical conditions which must obtain in the several circuits to the instruments. With this information at hand, changes in instrument connections necessitated by special instrument transformer requirements, may be made more readily than at present.

(2) To secure uniformity of all connection diagrams in respect to current and voltage transformer connections, both primary and secondary. This will insure that all instruments and electricity meters of the same or different manufacture, which belong to the same general class, may be *readily* connected to operate on the same current and voltage transformers.

(3) To adopt as standard those voltage transformer primary connections which are consistent with the requirements

of safe high-tension compartment construction. Such connections will also lend themselves to the requirements of the synchronizing apparatus, instruments and electricity meters on consumer's premises.

2—*Exhibits*

See Exhibits Nos. 1, 2, 3, 4 and 5, with notes, to which attention is called.

3—*Transformer Polarities*

At the present time, so far as is known, there is no uniformity of practise among manufacturers regarding the relative instantaneous polarities between primary and secondary windings of current and voltage transformers. For instance, certain manufacturers design transformers as shown by Sketch No. 1, Fig. 2,

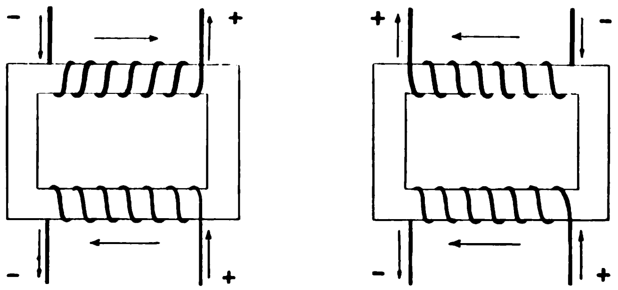


FIG. 2. DIAGRAMS SHOWING TWO METHODS OF TRANSFORMER CONSTRUCTION

and others as shown by Sketch No. 2, Fig. 2. Further, on some transformers no markings are placed on the terminals to indicate instantaneous polarities.

The terminals on all instrument transformers should be arranged alike as regards instantaneous polarities, and the connections represented by Sketch No. 2, Fig. 2, are recommended as preferable. An instantaneous positive polarity should be stamped on the respective terminals of the primary and secondary windings. This might well apply not only to instrument transformers but to all other transformers.

4—*Instrument Ratings*

Ratings of all instruments should be marked on the instrument, and should include the following:

(a) Secondary amperes

(b) Secondary volts
(c) Cycles
(d) Current transformer ratio
(e) Voltage transformer ratio
(f) Volt-amperes consumed by potential coils of the instrument
(g) Volt-amperes consumed by current coils of the instrument

The last two are of value in determining the necessary potential and current transformer capacities required to supply the potential and current coils of the instruments on their respective circuits.

5—*Instrument Terminals*

All terminals of instruments should be stamped with a designating letter for use in connection with the wiring diagram. The instantaneous positive polarity of all coils should be stamped on the terminals. The latter stamping serves also to readily identify the terminals of respective coils.

6—*Connection Diagrams*

Connection diagrams should be prepared covering all conditions under which the instrument may be connected. For example, on 3-phase systems connections should be given for operating on delta-connected and on star-connected voltage transformers.

7—*Grounding*

The casings of all instrument transformers should be grounded, and the manufacturer should provide a suitable lug, stud or binding post, conveniently located, for this purpose. This should also apply to load transformers. No fuses, resistances or instrument windings should be placed in the ground wire, between the ground and any instruments or transformers.

8—*For other suggested changes see notes with the several exhibits*

Figs. 4, 6 and 8 have been prepared simply to bring out the general method suggested and are not intended as wiring diagrams of specific instruments.

EXHIBIT 1

CONTRASTED EXAMPLES OF MANUFACTURERS' CONNECTION DIAGRAM AND SUGGESTED STANDARD FORM OF DIAGRAM

(Three-phase, 3-wire, power factor meter—high-tension switch-board type)

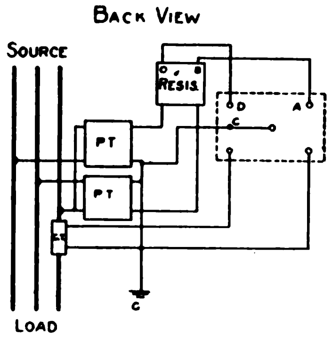


FIG. 3. DIAGRAM OF CONNECTIONS AS FURNISHED BY A MANUFACTURER

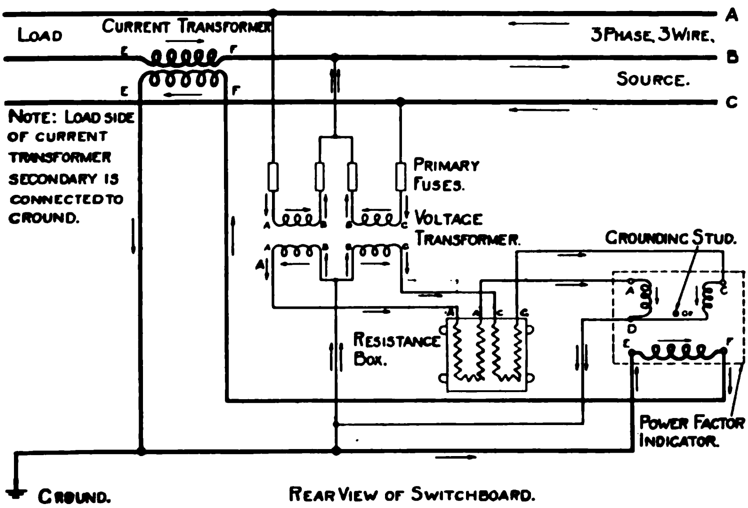


FIG. 4. SUGGESTED STANDARD FORM OF DIAGRAM FOR THE INSTRUMENT SHOWN IN FIG. 3

Leads from primary circuit to voltage transformers should not cross.

Include ground connection to instrument cases, as this is not sufficiently cared for in grounding the transformer secondaries. If grounding stud is furnished on the instrument case, it should be marked as such on the diagram.

Indicate the internal connections between terminals of all instruments, resistance boxes, etc. Inductive windings or inductances should be represented by a spiral, and non-inductive windings or resistances by a zig-zag line.

All instrument terminals should be stamped with a designating letter and the diagrams should be lettered accordingly.

Mark prominently on the diagram, "REAR VIEW" or "FRONT VIEW" of each instrument, apparatus or entire arrangement, as the case may be.

No fuse resistances or instrument windings should be placed in the ground wire between the ground and any instruments or transformers.

Indicate by the use of arrows on all connection diagrams the instantaneous direction of current flow in both primary and secondary current and voltage circuits of the transformers, and also in the coils of the instruments.

The lines which designate the secondary leads of the current transformer should be drawn heavier in the diagram than the primary or secondary leads of the voltage transformers, in order to readily distinguish the two. The primary leads of the current transformer should be heavier than either, establishing some standard thickness of line, in proportion to a ratio of 1, 2, 3 and 4.

Utilize a standard representation of all primary and secondary connections to current and voltage transformers (see Exhibit 5).

For star-connected current transformer secondaries, connect directly to ground the secondary lead which is at the load end of the transformer. This preference for the load end is simply to establish uniform practise.

The different classes of circuits for which each instrument is adapted should be noted on the diagram.

EXHIBIT 2

CONTRASTED EXAMPLES OF MANUFACTURERS' CONNECTION DIAGRAM AND SUGGESTED STANDARD FORM OF DIAGRAM

(Three-phase, 3-wire, indicating wattmeter—high-tension switch-board type)

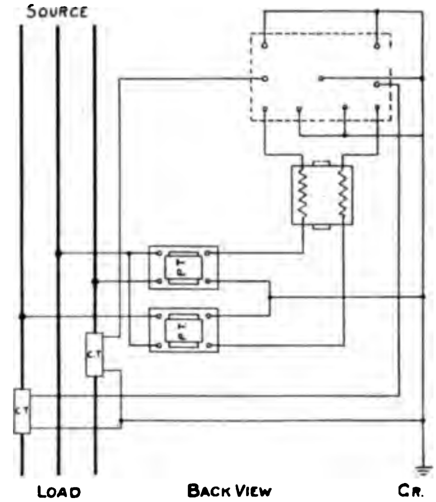


FIG. 5. DIAGRAM OF CONNECTIONS AS FURNISHED BY A MANUFACTURER

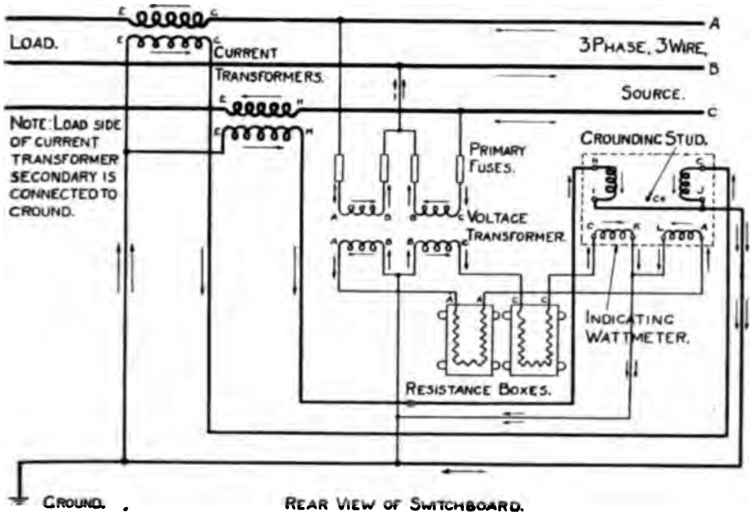


FIG. 6. SUGGESTED STANDARD FORM OF DIAGRAM FOR THE INSTRUMENT SHOWN IN FIG. 5

NOTES ON THE ABOVE DIAGRAMS

(The notes listed in Exhibit No. 1 apply here)

EXHIBIT 3

EXAMPLE OF MANUFACTURERS' CONNECTION DIAGRAM, WITH CERTAIN CRITICISMS

(Three-phase, 4-wire, indicating wattmeter—high-tension switch-board type)

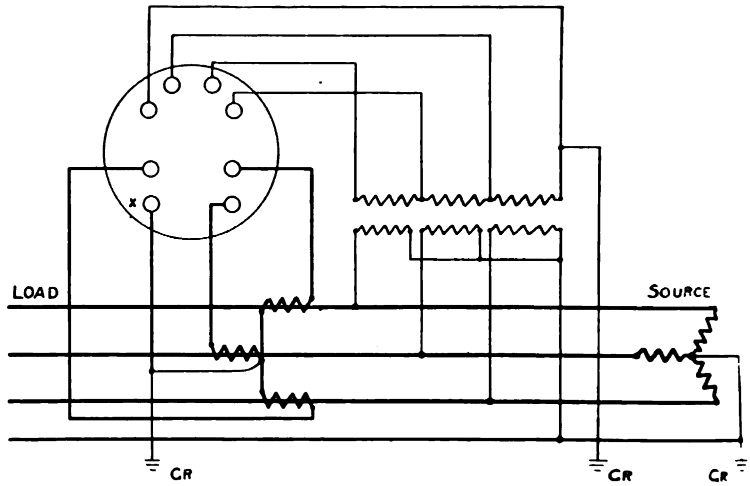


FIG. 7. DIAGRAM OF CONNECTIONS AS FURNISHED BY A MANUFACTURER

CRITICISMS OF THE ABOVE DIAGRAM

The manufacturer should arrange the terminals of all instruments so as to fit the scheme of standard representation of all primary and secondary connections to current and voltage transformers. For instance, rather than reverse the winding of one current transformer as shown in the diagram, the manufacturer should make the reversed connection inside the instrument.

Again, as a standard practise, the secondaries of the three voltage transformers should be connected in delta, ***at a point near the transformers.*** In the diagram, the manufacturer has completed, or closed, the delta connection inside of the instrument.

The current terminal marked X is the common junction of the three current windings of the instrument. This is bad practise. Each current winding should be independent of all other windings in the instrument and should consequently have two terminals. The need for this is apparent if current-reversing

vitches are to be used, as on circuits where the direction of ›rmal energy flow is subject to reversal.

The instrument as furnished had a grounding stud on the ise. None is shown in the diagram.

No specific note is made on the diagram as to whether "REAR IEW" or "FRONT VIEW" is shown.

No internal connections are indicated on the diagram of the strument.

No arrows are shown to indicate the instantaneous direction : current flow.

Other breaches of the recommendations suggested under xhibit I should be noted.

EXHIBIT 4

EXAMPLE OF THE READY COMBINATION OF TWO OR MORE INSTRUMENT DIAGRAMS, WHEN EACH DIAGRAM HAS BEEN PREPARED ACCORDING TO THE STANDARD REPRESENTATION OF CURRENT AND VOLTAGE TRANSFORMER CONNECTIONS

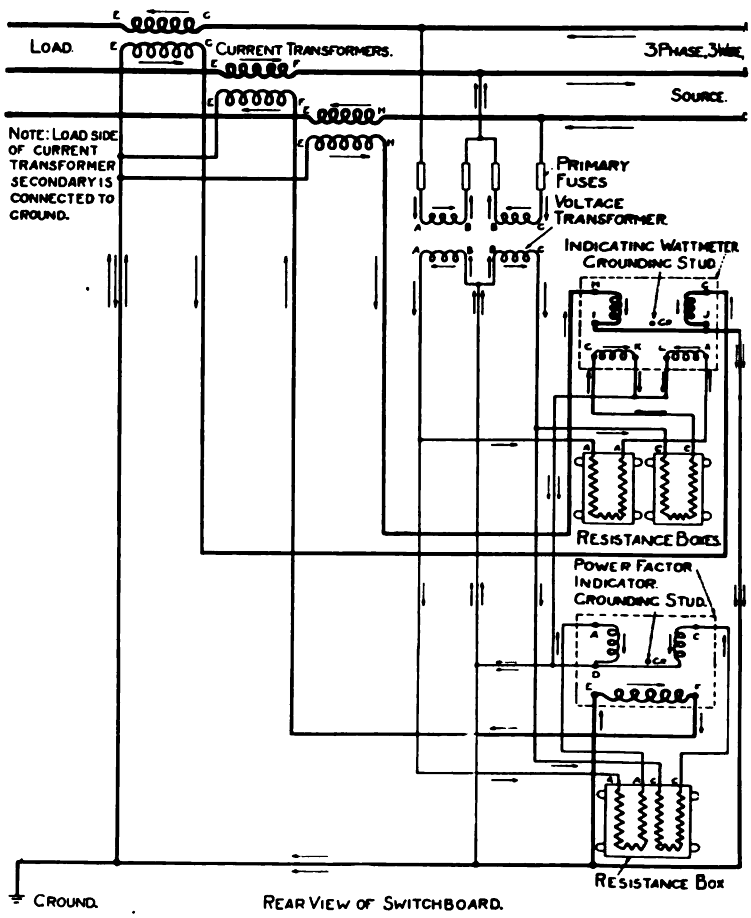
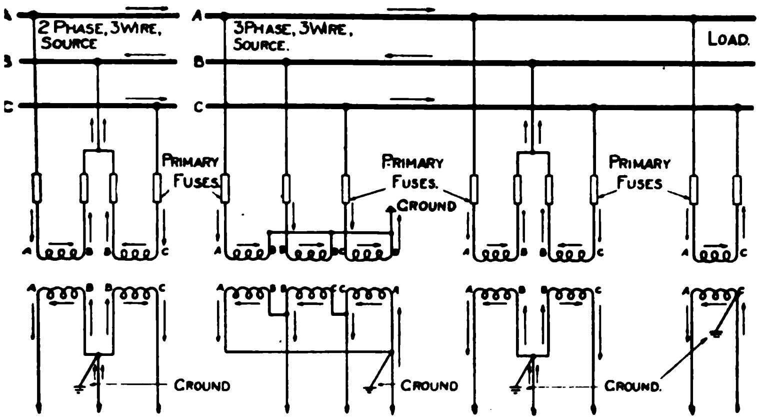


FIG. 8. A COMBINATION OF DIAGRAMS SHOWN IN FIGS. 4 AND 6

NOTE: Manufacturers Figs. 3 and 5, which are not prepared according to the standard representation of voltage transformer connections, cannot be combined as above without changes in external connections to the instrument.

EXHIBIT 5

(AMPLE OF THE APPLICATION OF THE FOREGOING NOTES TO LOAD OR VOLTAGE TRANSFORMERS



Front View

'ig. 9. Proper Arrangement of Diagrams and Markings for Voltage and Load Transformers

\ COMPARATIVE STUDY OF CONTINUOUS-CURRENT WATT-HOUR METERS

The Washington Bureau of Standards recently made a com-arative study of American continuous-current watt-hour meters. This study comprised much interesting and valuable data which, although not available at the present time will be published in the near future by the Bureau of Standards and can be procured upon application to that Bureau.

MAXIMUM-DEMAND DEVICES

PRINTOMETERS

Service tests on the printometer during the past year have brought to light several weak points and the manufacturers have recently made several changes in the device in order to eliminate these faults.

Printing and Cyclometer Coils

The coils formerly used were sometimes found to be sluggish and frequently burned out. The manufacturers believe they have entirely eliminated this trouble by changing over to iron-clad coils.

This feature will allow the coils to be permanently connected in the circuit without burning out. The power of the coils is greatly increased with a large decrease in current consumption. This is shown in the following comparison:

PRINTING COILS

Volts	Amperage, old coil	Amperage, new coil
110 volts a-c.	1.5	0.6
220 volts a-c.	1.0	0.3
110 volts d-c.	0.7	0.3
18 volts battery	5.5	2.3
	CYCLOMETER COILS	
110 volts a-c.	0.3	0.15
220 volts a-c.	0.1	0.05
110 volts d-c.	0.1	0.05
18 volts battery	1.0	0.05

In addition the plungers are highly polished, allowing of free and smooth action.

Contact-Making Device on Meter Register

This feature of the device formerly consisted of a commutator placed upon one of the spindles of the meter dial train, arranged with a slip-ring having connected to it various numbers of bars and three contact brushes, one bearing on the slip-ring and the other two placed diametrically opposite each other in the path of the bars, alternately closing the circuit through the cyclometer coil.

This form of contact device has been replaced with a new, almost frictionless and positive style of contact.

A highly polished brass ratchet wheel is mounted on one of the spindles of the register, insulated from the spindle by means of a fibre bushing. Two polished steel spring brushes rest diametrically opposite on the ratchet, thus allowing first one and then the other brush to drop off of a ratchet tooth at equal intervals. A platinum-iridium point is staked in each of these brushes and as the brush falls off the ratchet tooth, this point makes contact with another platinum-iridium point which is carried by a second spring leaf running parallel to the brush. The mechanism consists, therefore, of one ratchet wheel, two spring brushes, each carrying a platinum point, and two spring leaves also with a contact point each.

The two brushes resting on the ratchet wheel are charged constantly with line potential. Thus, when these drop alternately

on the two leaves which are connected to the cyclometer coil, the usual two-way circuit is obtained. The manufacturers claim that this style of contact is practically frictionless.

The contact breaking mechanism in the printometer has been re-designed. The shape of the curve upon which the contact brush rides has been changed so that the same tension will obtain throughout the entire motion. The contact brushes riding on this wheel, formerly made of phosphor bronze, are made of a special high resistance contact metal, and are reinforced at the point where they are fastened to the holding studs.

All leads connected from the printometer coils are attached to the terminal studs in the base by means of binding posts, instead of being soldered as before. This enables ready removal of the printometer mechanism from the base without removing the base from the switchboard, as was necessary when these leads were soldered.

All insulating washers in the printometer are now made of mica, as fiber which was formerly used was found to contract and expand with changes in temperature and moisture.

The rotating wheels are equipped with brass bushings, in order to reduce wear.

Additional bosses have been cast in the center of the base which permit the fastening of the back plate of the printometer to the center of the base, in order to prevent the instrument being thrown out of alignment when the case is fastened down by the thumb nut.

Your Committee has endeavored to induce other manufacturers to devise reasonably low-priced instruments that will properly indicate or record the maximum demand, but although several manufacturers have been working diligently, they are not yet in a position to submit any maximum-demand meters. Three different manufacturers, however, hope to be able to show some devices in the meter exhibit at the present Convention.

WESTINGHOUSE WATT-HOUR DEMAND METER

The meter here described has been designed to meet the much-felt need for an instrument which will measure maximum demand. Instead of following the general practise of supplying an attachment to a watt-hour meter, this device is a self-contained unit, combining the characteristics of a standard watt-hour meter, an

indicating wattmeter and an escapement form of time element in a single instrument. The single-phase meter is entirely contained in a case 7 inches in diameter, having the appearance of a standard watt-hour meter, and it is installed as an ordinary watt-hour meter and requires no additional apparatus or wiring. The maximum demand is indicated directly in kilowatts by a pointer sweeping over a 4-inch dial, the integrated load being registered on the

FIG. 10. WESTINGHOUSE WATT-HOUR DEMAND METER

usual 4-dial counter. The demand pointer is reset by pressing a button on top of the meter cover, thus making it unnecessary to open the meter. The reset button is sealed after each reading.

Instrument will be supplied of all standard capacities for both single and polyphase service with 5, 15 or 30-minute intervals, as desired.

The advantage gained by the elimination of the clock is obvious, while the manufacturer claims that the mechanism is so

mple that the up-keep and attention will be little greater than at of an ordinary watt-hour meter.

The general appearance of the single-phase instrument is own in Fig. 10. The instrument consists of a watt-hour meter cluding electromagnet, permanent magnet and aluminum disc. second or auxiliary disc is supported above the main disc by jewel ball-bearing so that it can move freely in the air gap of e electromagnet without interfering with the main disc. The xiliary disc is readily accessible by removing the four screws lding the electromagnet in place.

The series and shunt fluxes pass through both discs, inducg eddy currents which react on these fields in the usual manner. oducing a torque proportional to the load. The two discs are tirely independent, the auxiliary disc being so shaped that it es not interfere with the accuracy of the main disc which tates at a speed always proportional to the load. The auxiliary aft carries a spiral spring at its upper end, the tension of which poses the deflection of the disc, thus forming an indicating watteter. Hence, if no other mechanism were introduced, the xiliary disc would instantly deflect through an arc proportional the wattage.

The auxiliary shaft is, however, geared to an escapement heel which engages with a claw. A forked lever fixed to the w shaft is caused to oscillate by an eccentric geared to the ain disc. The mechanism is very similar in priniciple to the dinary clock, the auxiliary disc furnishing the power for drivg the escapement like a mainspring, the rate of movement being ntrolled by the motion of the main disc which performs the nctions of a balance wheel. The escapement wheel and claw ve radial teeth, thus preventing an interchange of energy tween the two discs. It is to be observed that the main disc is t required to furnish any power whatever, except the negligible ount needed to oscillate the escapement claw.

It is evident from the foregoing that the auxiliary disc will vance step by step at a rate proportional to the speed of the in disc until the spring tension balances the torque developed the disc. The demand pointer is driven by a dog on the auxry shaft and is held in the position of maximum deflection by ine-toothed ratchet and pawl. The pointer is reset manually pressing a button on top of the cover, which raises the pawl.

A light spring returns the pointer to its initial position. A second ratchet and pawl on the auxiliary shaft allow the auxiliary disc, under spring tension, to drop back to equilibrium when the load falls below the maximum, but prevents its being deflected to the former maximum position until allowed to do so by the escapement, as before.

The time required to reach equilibrium when any constant load is passed through the instrument is a constant, since the deflection and rate of deflection vary in direct proportion. For example, if we double a certain load, the rate at which the pointer moves across the scale is doubled, but since the distance it must move is doubled, due to double torque, the time required is constant, notwithstanding the absence of a clock. A mathematical analysis of the instrument shows that the deflection for any load which does not continue long enough for the instrument to reach equilibrium is equal to the integrated load, divided by the time interval. Equal products of load and time produce the same deflection, provided the duration of the load is less than the time interval of the instrument.

In general, the instrument will indicate a constant load in kilowatts which, if multiplied by the time interval, will give the maximum integrated load corresponding to the time interval of the instrument.

WESTINGHOUSE TYPE U GRAPHIC METERS—SWITCHBOARD AND PORTABLE

The type U meters make a continuous record, covering a week's time on a single strip of paper.

Operation

The meter consists of a solenoid and core acting directly on an arm that carries the recording pen, and a continuous strip of paper moved uniformly by a clock mechanism. To overcome the slight friction of the pen on the paper, the solenoid is made very powerful in its action. Its action is controlled by a heavy spring, which also eliminates any inaccuracies due to slight errors in leveling. The energy consumed by the mechanism is 50 watts.

Case

The meter is contained in a metal case having a glass window through which the movement of the pen can be observed. The

standard meter as regularly furnished is adapted for either switchboard mounting or portable use. A hinged handle at the top makes the meter convenient to carry about, and this handle can be easily removed when the meter is mounted on a switchboard or wall.

The pen is of the V-point type. It holds sufficient ink to last for one to three weeks, depending on the amount of variations in

FIG. 11. WESTINGHOUSE TYPE U GRAPHIC INSTRUMENT

the circuit; the more irregular the line drawn, the more ink will be used.

The meters are furnished regularly as voltmeters, 2-wire and 3-wire ammeters.

RECENT DEVELOPMENTS

During the past year the General Electric Co. has developed and placed on the market a mercury watt-hour meter designed for use on railway cars. The meter is contained in a cast aluminum-alloy case, and all parts, with the exception of the shunt, which is in a compartment in the back of the case, are mounted on a cast aluminum frame completely insulated from the base and cover. The rotating element or armature is a cupped copper punching attached to a shaft which is carried in a ring stone end stone

bearing at the bottom, and a ring stone bearing at the top. Th end stone bearing is secured to the bottom of the German silve vessel which serves as a container for the rotating armature an the mercury in which it is immersed. The immersion of the arma-ture in mercury does away with the commutator, frictional con-tacts and sparking troubles.

The mercury watt-hour meter is of rugged construction t

Fig. 12. G. E. Type I-10 Meter, With Glass Cover

withstand the excessive vibration incidental to railway servic The case is made dust-proof by accurately machining the surfa of the cover which rests on the base, and by the use of a heavy fe dust pad as a further safeguard.

During the year the General Electric Co. has produced a typ I-10 meter for use on 25 cycles, and at present can furnish th

type I-10 meter with a glass cover, and also with a 4-circle dial, if desired.

Several changes have been made in the type I-10 meter, the most important of which are as follows:

Loss in potential circuit has been reduced to 1.5 watts (at 110 volt 60 cycle).

Loss in current circuit has been reduced to 0.5 watts (at 110 volt 60 cycle).

While the micrometer light load adjustment has been retained the method has been changed. In place of two thumb-screws, one on each side of the meter, the light load adjustment is now made

FIG. 13. WESTINGHOUSE TYPE OA METER, WITH GLASS COVER

with one screw through the frame on the right-hand side facing the meter, and operated by a screwdriver. This method provides an easy and stable adjustment. The method of clamping the full load adjusting screw has also been changed. The clamping screw is now manipulated from the front instead of on the side.

The Westinghouse Co. reports that it is now in a position to furnish the *OA* meter *top-connected* up to 25 amperes, 2 and 3-wire, 60 cycle. It can also furnish the *bottom-connected* up to 300 amperes, 2-wire and 150 amperes, 3-wire, 133, 60 and 25 cycle, all self-contained.

The same company has recently placed on the market a line of portable indicating meters as follows:

TYPES PC AND PD PORTABLE METERS

Type PC, a-c. or d-c. voltmeters
Type PC, a-c. or d-c. wattmeters
Type PC, iron loss voltmeters
Type PC, power-factor meters
Type PD, frequency meters

FIG. 14. TYPE PC A-C. OR D-C. VOLTMETER

These are direct-reading instruments for general testing and laboratory work, particularly on alternating-current, Type PC voltmeters, wattmeters, and power-factor meters operate on the moving coil principle, and type PD frequency meters on an adaptation of the induction principle. The damped character of the indications enables readings to be taken quickly and accurately.

Construction

The movement is mounted as a unit and can be removed complete after taking off the face-plate. The face-plate makes a dust-proof joint with an inner aluminum mounting plate. The type PC meters have a laminated iron shield riveted to the aluminum mounting plate, protecting the movement both from dust and from stray magnetic fields. The type PD meters also have a dust-proof case construction. The weight of the moving element is in all cases low, and the torque is relatively high.

The Fort Wayne Electric Works are now in a position to furnish the type K-4 meter for 25 cycle, in sizes from 5 to 100 amperes, 220-volt, 3-wire, and 5 to 100 amperes, 110-volt or 220-volt, 2-wire. They are also furnishing the 25-cycle type K-3 meter self-contained.

The Sangamo Electric Co. has recently produced a somewhat improved type of direct-current mercury meter known as the type D-4. This meter is similar to the standard type D meter, but the manufacturers claim that it has an improved armature and shunt magnet, giving considerably higher torque and better performance.

The same company has recently developed a polyphase induction watt-hour meter, as shown in Figs. 15 and 16. This meter has two elements carried on one main grid, each element in itself being exactly like the complete element of the Type H single-phase meter, the disks of the two elements being mounted on a single shaft.

The manufacturer claims that this meter has a full load torque of 85 millimeter grams, and the moving element weighs 32 grams, slightly more than double the weight of the moving element in the single-phase meter. The ratio of torque to weight is, therefore, approximately the same as in the single-phase, 2.6. The electrical performance of the meter, that is, on varying load, frequency, voltage, temperature, etc., is exactly the same as that of the single-phase already described.

Type H polyphase meters are furnished either with pressed aluminum cover and glass windows, or with full pressed glass cover, at no extra charge.

The Duncan Electric Manufacturing Co. has recently placed on the market a new direct-current meter known as the Model E-½. This new meter is manufactured only in the smaller sizes, and the manufacturer claims that in many respects it is superior to the older models.

FIG. 15. SANGAMO INDUCTION POLYPHASE WATT-HOUR METER, WITH COVER

FIG. 16. SANGAMO INDUCTION POLYPHASE WATT-HOUR METER, COVER REMOVED

RMATION FOR FUTURE REVISION OF THE LECTRICAL METERMAN'S HANDBOOK

pter 15 of the Handbook is a treatise on watt-hour meter and test formulae. Your Committee notes that the en therein do not apply to 25-cycle meters, and the fol- bles are supplemental to those given.

'S AND REGISTER DATA FOR TYPES I, I-8, IP, IP-2, IP-3 AND IP-4 THOMSON SINGLE-PHASE WATT-HOUR METERS

Capacities 3 to 300 ampere, 25 cycle

106 to 120 volt

Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
10	0.4	0.4	1	250	25,000
10	0.6	0.6	1	166⅔	16,666⅔
10	1.25	1.25	1	80	8,000
10	2.0	2.0	1	50	5,000
10	3.0	3.0	1	33⅓	3,333⅓
10	6.0	6.0	1	16⅔	1,666⅔
10	10.	10.	1	10	1,000
10	12.5	12.5	10	80	8,000
10	20.	20.	10	50	5,000
10	25.	25.	10	40	4,000
10	40.	40.	10	25	2,500

212 to 240 volt

10	.75	.75	1	133⅓	13,333⅓
10	1.25	1.25	1	80	8,000
10	2.5	2.5	1	40	4,000
10	4.0	4.	1	25	2,500
10	6.0	6.	1	16⅔	1,666⅔
10	12.5	12.5	10	80	8,000
10	20.	20.	10	50	5,000
10	25.	25.	10	40	4,000
10	40.	40.	10	25	2,500
10	50.	50.	10	20	2,000
10	75.	75.	10	13⅓	1,333⅓

CONSTANTS AND REGISTER DATA FOR TYPES D-3 AND D-4 THOMSON POLYPHASE WATT-HOUR METERS, CAPACITIES 3 TO 600 AMPERE, 25 CYCLE

106 to 120 volt

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
3	10	1.	1.	1	100	10,000
5	10	1.5	1.5	1	66⅔	6,666⅔
10	10	3.	3.	1	33⅓	3,333⅓
15	10	5.	5.	1	20	2,000
25	10	7.5	7.5	1	13⅓	1,333⅓
50	10	15.	15.	10	66⅔	6,666⅔
75	10	20.	20.	10	50	5,000
100	10	30.	30.	10	33⅓	3,333⅓
150	10	40.	40.	10	25	2,500
200	10	60.	60.	10	16⅔	1,666⅔
300	10	100.	100.	100	100	10,000
400	10	125.	125.	100	80	8,000
600	10	200.	200.	100	50	5,000

212 to 240 volt

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
3	10	2.	2.	1	50	5,000
5	10	3.	3.	1	33⅓	3,333⅓
10	10	6.	6.	1	16⅔	1,666⅔
15	10	10.	10.	1	10	1,000
25	10	15.	15.	10	66⅔	6,666⅔
50	10	30.	30.	10	33⅓	3,333⅓
75	10	40.	40.	10	25	2,500
100	10	60.	60.	10	16⅔	1,666⅔
150	10	75.	75.	10	13⅓	1,333⅓
200	10	125.	125.	100	80	8,000
300	10	200.	200.	100	50	5,000
400	10	250.	250.	100	40	4,000
600	10	400.	400.	100	25	2,500

400 to 480 volt

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
3	10	4.	4.	1	25	2,500
5	10	6.	6.	1	16⅔	1,666⅔
10	10	12.5	12.5	10	80	8,000
15	10	20.	20.	10	50	5,000
25	10	30.	30.	10	33⅓	3,333⅓
50	10	60.	60.	10	16⅔	1,666⅔
75	10	75.	75.	10	13⅓	1,333⅓
100	10	125.	125.	100	80	8,000
150	10	150.	150.	100	66⅔	6,666⅔
200	10	250.	250.	100	40	4,000
300	10	400.	400.	100	25	2,500
400	10	500.	500.	100	20	2,000
600	10	750.	750.	100	13⅓	1,333⅓

500 to 600 volt

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
3	10	5.	5.	1	20	2,000
5	10	7.5	7.5	1	13⅓	1,333⅓
10	10	15.	15.	10	66⅔	6,666⅔
15	10	25.	25.	10	40	4,000
25	10	40.	40.	10	25	2,500
50	10	75.	75.	10	13⅓	1,333⅓
75	10	100.	100.	10	10	1,000
100	10	150.	150.	100	66⅔	6,666⅔
150	10	200.	200.	100	50	5,000
200	10	300.	300.	100	33⅓	3,333⅓
300	10	500.	500.	100	20	2,000
400	10	600.	600.	100	16⅔	1,666⅔
600	10	1,000.	1,000.	100	10	1,000

CONSTANTS AND REGISTER DATA FOR THOMSON TYPE I-10, SINGLE-PHASE WATT-HOUR METERS

Capacities 5 to 25 ampere, 25 cycle

106 to 120 volt

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
5	10	0.3	0.3	1	333⅓	33,333⅓
10	10	0.6	0.6	1	166⅔	16,666⅔
15	10	1.	1.	1	100	10,000
25	10	1.5	1.5	1	66⅔	6,666⅔
			212 to 240 volt			
5	10	0.6	0.6	1	166⅔	16,666⅔
10	10	1.25	1.25	1	80	8,000
15	10	2.	2.	1	50	5,000
25	10	3.	3.	1	33⅓	3,333⅓

The constants and register data for Westinghouse 25-cycle meters are the same as those given in the Handbook with the exception that the register ratios (R_r) of recent OA meters, of all frequencies, have been changed, all other data given in the tables remaining unchanged.

CONSTANTS AND REGISTER DATA FOR FORT WAYNE TYPES K, K-1, K-2 AND K-3, SINGLE-PHASE METERS

25 to 35 cycle, house pattern

100 to 125 volt

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
5	10	18.	0.5	1	200	20,000
10	10	36.	1.	1	100	10,000
15	10	54.	1.5	1	66⅔	6,666⅔
20	10	72.	2.	1	50	5,000
25	10	90.	2.5	1	40	4,000
30	10	108.	3.	1	33⅓	3,333⅓
40	10	144.	4.	1	25	2,500
50	10	180.	5.	1	20	2,000
60	10	216.	6.	1	16⅔	1,666⅔
75	10	270.	7.5	1	13⅓	1,333⅓
80	10	288.	8.	1	12½	1,250
100	10	360.	10.	10	100	10,000
125	10	450.	12.5	10	80	8,000
150	10	540.	15.	10	66⅔	6,666⅔
200	10	720.	20.	10	50	5,000
300	10	1,080.	30.	10	33⅓	3,333⅓
400	10	1,440.	40.	10	25	2,500
600	10	2,160.	60.	10	16⅔	1,666⅔
800	10	2,880.	80.	10	12½	1,250

200 to 250 volt

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
5	10	36.	1.	1	100	10,000
10	10	72.	2.	1	50	5,000
15	10	108.	3.	1	33⅓	3,333⅓
20	10	144.	4.	1	25	2,500
25	10	180.	5.	1	20	2,000
30	10	216.	6.	1	16⅔	1,666⅔
40	10	288.	8.	1	12½	1,250
50	10	360.	10.	10	100	10,000
60	10	432.	12.	10	83⅓	8,333⅓
75	10	540.	15.	10	66⅔	6,666⅔
80	10	576.	16.	10	62½	6,250
100	10	720.	20.	10	50	5,000
125	10	900.	25.	10	40	4,000
150	10	1,080.	30.	10	33⅓	3,333⅓
200	10	1,440.	40.	10	25	2,500
300	10	2,160.	60.	10	16⅔	1,666⅔
400	10	2,880.	80.	10	12½	1,250
600	10	4,320.	120.	100	83⅓	8,333⅓
800	10	5,760.	160.	100	62½	6,250

CONSTANTS AND REGISTER DATA FOR FORT WAYNE TYPES K, K-1, K-2 AND K-3, SINGLE-PHASE METERS

25 to 35 cycle, house pattern

400 to 499 volt

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
5	10	72.	2.	1	50	5,000
10	10	144.	4.	1	25	2,500
15	10	216.	6.	1	16⅔	1,666⅔
20	10	288.	8.	1	12½	1,250
25	10	360.	10.	10	100	10,000
30	10	432.	12.	10	83⅓	8,333⅓
40	10	576.	16.	10	62½	6,250
50	10	720.	20.	10	50	5,000
60	10	864.	24.	10	41⅔	4,166⅔
75	10	1,080.	30.	10	33⅓	3,333⅓
80	10	1,152.	32.	10	31¼	3,125
100	10	1,440.	40.	10	25	2,500
125	10	1,800.	50.	10	20	2,000
150	10	2,160.	60.	10	16⅔	1,666⅔
200	10	2,880.	80.	10	12½	1,250
300	10	4,320.	120.	100	83⅓	8,333⅓
400	10	5,760.	160.	100	62½	6,250
600	10	8,640.	240.	100	41⅔	4,166⅔
800	10	11,520.	320.	100	31¼	3,125

500 to 625 volt

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
5	10	90.	2.5	1	40	4,000
10	10	180.	5.	1	20	2,000
15	10	270.	7.5	1	13⅓	1,333⅓
20	10	360.	10.	10	100	10,000
25	10	450.	12.5	10	80	8,000
30	10	540.	15.	10	66⅔	6,666⅔
40	10	720.	20.	10	50	5,000
50	10	900.	25.	10	40	4,000
60	10	1,080.	30.	10	33⅓	3,333⅓
75	10	1,350.	37.5	10	26⅔	2,666⅔
80	10	1,440.	40.	10	25	2,500
100	10	1,800.	50.	10	20	2,000
125	10	2,250.	62.5	10	16	1,600
150	10	2,700.	75.	10	13⅓	1,333⅓
200	10	3,600.	100.	100	100	10,000
300	10	5,400.	150.	100	66⅔	6,666⅔
400	10	7,200.	200.	100	50	5,000
600	10	10,800.	300.	100	33⅓	3,333⅓
800	10	14,400.	400.	100	25	2,500

CONSTANTS AND REGISTER DATA FOR FORT WAYNE TYPE K-4 WATT-HOUR METERS

25 to 35 cycle, house pattern

100 to 125 volt

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
5	10	0.5	0.5	1	200	20,000
10	10	1.	1.	1	100	10,000
15	10	1.5	1.5	1	66⅔	6,666⅔
20	10	2.	2.	1	50	5,000
25	10	2.5	2.5	1	40	4,000
40	10	4.	4.	1	25	2,500
50	10	5.	5.	1	20	2,000
75	10	7.5	7.5	1	13⅓	1,333⅓
100	10	10.	10.	1	10	1,000

200 to 250 volt

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
5	10	1.	1.	1	100	10,000
10	10	2.	2.	1	50	5,000
15	10	3.	3.	1	33⅓	3,333⅓
20	10	4.	4.	1	25	2,500
25	10	5.	5.	1	20	2,000
40	10	8.	8.	1	12½	1,250
50	10	10.	10.	1	10	1,000
75	10	15.	15.	10	66⅔	6,666⅔
100	10	20.	20.	10	50	5,000

CONSTANTS AND REGISTER DATA FOR SANGAMO TYPE H SINGLE-PHASE WATT-HOUR METERS, 25 CYCLE

110 volt, 2 wire

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
5	10	1,200.	⅓	1	600.	30,000
10	10	2,400.	⅔	1	300.	15,000
20	10	4,800.	1⅓	1	150.	7,500
30	10	7,200.	2	1	100.	5,000
40	10	9,600.	2⅔	1	75.	3,750
60	10	14,400.	4	1	50.	2,500
80	10	19,200.	5⅓	1	37.5	1,875
100	10	24,000.	6⅔	1	30.	1,500
150	10	36,000.	10	1	20.	1,000
200	10	48,000.	13⅓	1	15.	750
300	10	72,000.	20	10	100.	5,000
400	10	96,000.	26⅔	10	75.	3,750
500	10	120,000.	33⅓	10	60.	3,000
600	10	144,000.	40	10	50.	2,500
800	10	192,000.	53⅓	10	37.5	1,875
1,000	10	240,000.	66⅔	10	30.	1,500

220 volt, 2 and 3 wire

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
5	10	2,400.	$\frac{2}{3}$	1	300.	15,000.
10	10	4,800.	$1\frac{1}{3}$	1	150.	7,500.
20	10	9,600.	$2\frac{2}{3}$	1	75.	3,750.
30	10	14,400.	4	1	50.	2,500.
40	10	19,200.	$5\frac{1}{3}$	1	37.5	1,875.
60	10	28,800.	8	1	25.	1,250.
80	10	38,400.	$10\frac{2}{3}$	1	18.75	937.5
100	10	48,000.	$13\frac{1}{3}$	1	15.	750.
150	10	72,000.	20	10	100.	5,000.
200	10	96,000.	$26\frac{2}{3}$	10	75.	3,750.
300	10	144,000.	40	10	50.	2,500.
400	10	192,000.	$53\frac{1}{3}$	10	37.5	1,875
500	10	240,000.	$66\frac{2}{3}$	10	30.	1,500.
600	10	288,000.	80	10	25.	1,250.
800	10	384,000.	$106\frac{2}{3}$	10	18.75	937.5
1,000	10	480,000.	$133\frac{1}{3}$	10	15.	750.

POLYPHASE

110-volt polyphase same as 220-volt single-phase

220 volt, 25 cycle

Capacity in Amperes	Numerical Value of 1 Revolution of 1st Dial Hand	Test Constant (K_t)	Watt-hour Constant (K_h)	Numerical Value of Register Constant (K_r)	Register Ratio (R_r)	Gear Ratio (R_g)
5	10	4,800.	$1\frac{1}{3}$	1	150.	7,500.
10	10	9,600.	$2\frac{2}{3}$	1	75.	3,750.
20	10	19,200.	$5\frac{1}{3}$	1	37.5	1,875.
30	10	28,800.	8	1	25.	1,250.
40	10	38,400.	$10\frac{2}{3}$	1	18.75	937.5
60	10	57,600.	16	10	125.	6,250.
80	10	76,800.	$21\frac{1}{3}$	10	93.7	4,685.
100	10	96,000.	$26\frac{2}{3}$	10	75.	3,750.
150	10	144,000.	40	10	50.	2,500.
200	10	192,000.	$53\frac{1}{3}$	10	37.5	1,875.
300	10	288,000.	80	10	25.	1,250.
400	10	384,000.	$106\frac{2}{3}$	10	18.75	937.5
500	10	480,000.	$133\frac{1}{3}$	10	15.	750.
600	10	576,000.	160	100	125.	6,250.
800	10	768,000.	$213\frac{1}{3}$	100	93.7	4,685.
1,000	10	960,000.	$266\frac{2}{3}$	100	75.	3,750.

The constants and register data for Columbia 25-cycle meters are the same as those given in the Handbook.

It is recommended that the following changes in schedules for periodic testing be made in the Electrical Meterman's Handbook.

Page 356 now reads:

"The tendency in the case of induction meters, since the production of modern types, is to extend the period, whereas the maximum period of about one year is generally accepted for commutator type meters."

Change to read:

"The tendency since the production of modern types is to constantly extend the period as these newly designed meters come into more general use, the extension of the periods between tests applying to both induction and commutator meters."

The schedule for periodic tests now reads:

"The following is a suggestive schedule of routine periodic tests indicative of modern practise:

Modern Type Alternating-Current Induction Meters

All single-phase induction meters, 2-wire or 3-wire, up to and including 25 amperes rated capacity, to be tested once in 24 months.

All single-phase induction meters, 2-wire and 3-wire, over 25 amperes rated capacity, to be tested at least once in 12 months.

All polyphase induction meters up to and including 150 amperes, to be tested at least once in 12 months.

All polyphase induction meters over 150 amperes rated capacity, to be tested at least once in 6 months.

Continuous-Current Commutator Type Meters

All continuous-current commutator type meters, 2 or 3-wire, 110 or 220 volts, up to and including 25 amperes rated capacity, to be tested at least once in 12 to 15 months.

All continuous-current commutator type meters, 2 or 3-wire, 110 to 220 volts, 50 to 150 amperes rated capacity, to be tested at least once in 9 to 12 months.

All continuous-current commutator type meters rated at 150 amperes to 600 amperes, to be tested at least once in 6 months.

All continuous-current commutator type meters rated in excess of 600 amperes, to be tested every 3 months."

Change to read:

"The following is a suggestive schedule of routine periodic tests indicative of modern practise:

Modern Type Alternating-Current Induction Meters

All single-phase induction meters, 2-wire or 3-wire, up to and including 25 amperes rated capacity, to be tested once in 30 months.

All single-phase induction meters, 2-wire or 3-wire, over 25 amperes rated capacity, to be tested at least once in 24 months.

All polyphase induction meters up to and including 150 amperes, to be tested at least once in 24 months.

All polyphase induction meters over 150 amperes rated capacity, to be tested at least once in 12 months.

Continuous-Current Commutator Type Meters

All continuous-current commutator type meters, 2 and 3-wire, 110 to 220 volts, up to and including 25 amperes rated capacity, to be tested at least once in 18 months.

All continuous-current commutator type meters, 2 and 3-wire, 110 to 220 volts, 25 to 500 amperes rated capacity, to be tested at least once in 12 months.

All continuous-current commutator type meters, rated at 500 amperes and over, to be tested at least once in 6 months."

We feel that in making the changes suggested, the specifications of the Handbook will have the additional value gained by including a schedule which has been approved by a State commission.

ERRATA IN THE ELECTRICAL METERMAN'S HANDBOOK

When the Electrical Meterman's Handbook was compiled, a great volume of figures and data had to be assimilated in a very short time. It was realized by that Committee that, in spite of strenuous efforts to avoid errors, they would unavoidably creep in and that, in due time, a revision would be desirable. In the time which has elapsed since the book appeared the Committee has solicited criticisms and suggestions for future editions and has accumulated some errata which can be most beneficially utilized by publication in the Committee's report. These errata are therefore given below, and the Committee earnestly requests the members to send them any further points of improvement.

On page 32, in the definition for "Cathode," replace the word "enters" by the word "leaves."

On page 77, insert the following definition of a voltage transformer, after definition of voltage: "A stationary piece of apparatus for transforming, by electromagnetic induction, voltage or potential, from one circuit to another. This apparatus is used primarily in connection with meters or instruments."

On page 238, Fig. 192, the title should read: "Portable Wattmeter, Electro-dynamometer Type, Keystone."

On page 547, Fig. 372, in the last column, replace the number "493" by the number "500," and the number "1078" by the number "1077."

On page 729, Fig. 409, the title should read: "Thomson, Single-phase, Form C-4, Induction Watt-hour Meter."

On page 770, Fig. 435, revise last sentence of title to read: "Service Enters on the Left for Two-wire Meters and for Three-wire Meters Enters Upper Left-hand and Lower Right-hand Terminals."

On page 794, Fig. 459, the title of the upper view should be: "Internal View of Thomson Rectangular Pattern, Type DF-2. Polyphase, Induction Watt-hour Meter."

On page 1070, left-hand column, 8th line from bottom, should read: "shunted type, 988, 989."

On page 1071, right-hand column, between the fifth and sixth lines from bottom, insert: "Potential transformer, see voltage transformer."

BIBLIOGRAPHY

On page 87 of the Electrical Meterman's Handbook is given a partial list of books and articles on subjects intimately related to the measurement of electricity. It was the idea of those preparing the Handbook that the list would be merely suggestive of a complete list of this kind, and in furtherance of this idea, the following additional list is given of publications which have recently appeared. It is the earnest desire of your Committee that members submit to the chairman the title, author, date and place of appearance of any subject matter which should appear in this "Bibliography."

"The Proposed Revision of the Standards of Gas and Electric Service Under Consideration by the Railroad Rate Commission of Wisconsin." J. N. Cadby. Wisconsin Electrical Association, January, 1913.

"Law Creating the Public Utilities Commission of the District of Columbia." March 4, 1913.

"An Ordinance Providing for the Inspection of Gas Meters and Electric Meters." City of Norfolk, Va. March 29, 1913.

"General Data on Thomson Watt-hour Meters." General Electric Co. December, 1912. No. Y-188.

"Electrical Instruments and Meters in Europe." H. B. Brooks, U. S. Department of Commerce and Labor, Bureau of Foreign and Domestic Commerce. Special Agents Series No. 66.

"Outline of Design of Deflection Potentiometers, with Notes on the Design of Moving-coil Galvanometers." H. B. Brooks,

U. S. Department of Commerce and Labor, Bureau of Standards. Reprint No. 173.

"Deflection Potentiometers for Current and Voltage measurements." H. B. Brooks, U. S. Department of Commerce and Labor, Bureau of Standards. Reprint No. 172.

"Variation of Resistances with Atmospheric Humidity." Edward B. Rosa and Harold D. Babcock, Department of Commerce and Labor, Bureau of Standards. Reprint No. 73.

"Determination of the Constants of Instrument Transformers." P. G. Agnew and T. T. Fitch, Department of Commerce and Labor, Bureau of Standards. Reprint No. 130.

"Determination of the Ratio of Transformation and of the Phase Relations in Transformers." E. B. Rosa and M. G. Lloyd, Department of Commerce and Labor, Bureau of Standards. Reprint No. 116.

"Decision of Railroad Commission of Wisconsin." July 24, 1908. No. U.-21, *"In re* Standards for Gas and Electric Service in the State of Wisconsin."

ON WATT-HOUR METERS OPERATING ON VARIABLE LOADS:

Orlich & Schultze, *Elektrotchnik und Maschinenbau.* Vol. 27, 1909. (Science Abstracts B, 1909, No. 1030.)

Schmiedel, *Elektrotechnik und Maschinenbau.* Vol. 29, 1911. (Science Abstracts B, 1911, No. 671.)

L. T. Robinson, *Electrical Review,* (Chicago). Vol. 59, p. 1232, 1911.

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"Device for Measuring the Torque of Electrical Instruments." P. G. Agnew, Department of Commerce and Labor, Bureau of Standards. Reprint No. 145.

"Method of Measuring Electrical Instrument Torque." Janus, *Elektrotechnische Zeitschrift,* Vol. 26, 1905.

"Selection of Watt-hour Meters by Competitive Tests." *Electrical World,* Vol. 55, 1912.

"Portable Torque Balance." General Electric Co. Bulletin No. 4331.

"Meter Protective Devices." Wehrle & Hartmann, National Electric Light Association, December, 1912.

"A Comparative Study of American Continuous-Current Watt-hour Meters." T. T. Fitch and C. J. Huber, 1913. Department of Commerce and Labor, Bureau of Standards.

"Electricity Meters." H. G. Solomon, 1906.

"Electricity Meters." C. H. W. Gerhardi, 1906.

"Die Heutigen Ampere und Wattstundzahler Handbuch der Electrotechnik," II-6, 1908.

"Uber das Verhalten von Electrizitatszahlern, bei Schwankender Belastung." Orlich & Schulze, 1909. *Electrotechnik und Maschinenbau*, 27.

"Les Compteurs Electrique." L. Barbillion et C. Ferroux. 1910.

"Le Compteur Electrique." A. Durand. Atti Cong. Ap. El. Lurin., 1911.

"Reibung von Elektrizitatszahlern mit rotierendem Anker und Enfluss der Reibung auf die Fehlerkurve." Carl Schmiedel. Verein zur Beforderung de Gewerbfleisses. 1910, 1911.

"Uber das Verhalten von Fenariszahlern bei Schwankender Belastung." K. Schmiedel. *Electrotechnik und Maschinenbau*, 29, 555. 1911.

Der Electrizitatszahlern. R. Ziegenberg. 1912.

CO-OPERATION WITH PUBLIC SERVICE COMMISSIONS

Your Committee feels that one of its functions is to get in touch with various Public Utility Commissions as fast as they are organized, and begin with them to formulate rules and regulations which involve in any way electricity meters, their records or other operating features. With the Code for Electricity Meters and the Electrical Meterman's Handbook as definitely approved standard works, and the large experience of the Committee in the operation of meters for a foundation, it is believed that the Committee can be of service in thus co-operating with Commissions who require information and data relative to the performance of electricity meters under various conditions. Your Committee further believes that its presence at such meetings will tend to bring about greater uniformity in rules governing the use of electricity meters; and for the guidance of future committees it would appreciate an expression of opinion from the Association on this point.


COMMITTEE ON METERS.

The efforts of the Committee are met by the Commissions generally, with the greatest appreciation, and the co-operative attitude of these bodies and their willingness to accept suggestions are exemplified in the recent conference with the Wisconsin Railroad Commission, when standards embodied in the Electrical Meterman's Handbook and other authorities suggested by the Committee were given careful consideration by the Commission.

Your Committee has assumed it to be of interest to include in this report the laws, rulings and regulations affecting the measurement of electricity that have been put in force during the year.

The following are extracts from recent laws, ordinances, decisions and revisions affecting the control and regulation of the measurement of electricity by different commissions and governing bodies.

DISTRICT OF COLUMBIA

The Federal Congress has recently passed a law creating a Public Utilities Commission for the District of Columbia. While this Commission has been appointed, it has not yet formulated rules for the operation of electricity meters. Extracts from the law pertinent to this subject, however, are herewith cited.

Extracts from "Law Creating the Public Utilities Commission of the District of Columbia."

Section 8, Par. 21. "That the Commission shall ascertain and fix adequate and serviceable standards for the measurement of quality, pressure, initial voltage, or other condition pertaining to the supply of the product or service rendered by any public utility, and prescribe reasonable regulations for examining and testing such product or service and for the measurement thereof. It shall establish reasonable rules, regulations, specifications, and standards to secure the accuracy of all meters and appliances for measurements, and every public utility is required to carry into effect all orders issued by the Commission relative thereto.

Par. 22. "That the Commission shall provide for the examination and testing of any and all appliances used for the measuring of any product or service of a public utility. Any consumer or user may have any such appliance tested upon payment of the fees fixed by the Commission. The Commission shall declare and establish reasonable fees to be paid for testing such appliances on the request of the consumers or users, the fee to be paid

by the consumer or user at the time of his request, but to be paid by the public utility and repaid to the consumer or user if the appliance be found defective or incorrect to the disadvantage of the consumer or user.

Par. 23. "That the Commission may purchase such materials, apparatus, and standard measuring instruments for such examination and tests as it may deem necessary. The Commission, its agents, experts or examiners shall have power to enter upon any premises occupied by a public utility for the purpose of making the examinations and tests provided for in this section, and to set up and use on such premises any apparatus and appliances and occupy reasonable space therefor.

Par. 32. "That the Commission shall have power to adopt reasonable and proper rules and regulations relative to all inspections, tests, audits and investigations, and to adopt and publish reasonable and proper rules to govern its proceedings and to regulate the mode and manner of all investigations and hearings of public utilities and other parties before it.

Par. 33. "That the Commission shall keep itself informed as to the manner and method in which the business of all public utilities is conducted, and shall have the right to obtain from any public utility all necessary information to enable the Commission to perform its duties.

Par. 57. "The Commission shall appoint inspectors of electric meters, whose duty it shall be, when required by the Commission, to inspect, examine and ascertain the accuracy of any and all electric meters used or intended to be used for measuring and ascertaining the quantity of electric current furnished for light, heat or power by any person or corporation to or for the use of any person or corporation, and to inspect, examine and ascertain the accuracy of all apparatus for testing and proving the accuracy of electric meters; and when found to be or made to be correct the inspector shall stamp or mark all such meters and apparatus with some suitable device, which device shall be recorded in the office of the Commission. No corporation or person shall furnish, set, or put in use any electric meter the type of which shall not have been approved by the Commission or any meter not approved by an inspector of the Commission.

"Every gas corporation and electrical corporation shall provide, repair and maintain such suitable premises and apparatus

and facilties as may be required and approved by the Commission for testing and proving the accuracy of gas and electric meters furnished for use by it, and by which apparatus every meter may be tested.

"If any consumer to whom a meter has been furnished shall request the Commission in writing to inspect such meter, the Commission shall have the same inspected and tested; if the same, on being so tested, shall be found to be more than 4 per centum, if an electric meter, or more than 2 per centum, if a gas meter, defective or incorrect to the prejudice of the consumer, the inspector shall order the gas or electrical corporation forthwith to remove the same and to place instead a correct meter, and the expense of such inspection and test shall be borne by the corporation; if the same, on being so tested, shall be found to be correct, the expense of such inspection and test shall be borne by the consumer.

"The Commission shall prescribe such rules and regulations to carry into effect the provisions of this paragraph as it may deem necessary and shall fix uniform reasonable charges for the inspection and testing of meters upon complaint."

NORFOLK, VA.

The following is a copy of an ordinance taking effect March 29, 1913:

An Ordinance Providing for the Inspection of Gas Meters and Electric Meters

"Be it ordained by the Council of the City of Norfolk, Virginia, as follows:

Section 1. "That in addition to the present duties of the Superintendent of Electrical Affairs (City Electrician), and without extra compensation therefor, he shall, under the direction and control of the Board of Control, make accurate and impartial inspections and tests of gas meters and electric meters in the City of Norfolk.

Section 2. "No corporation or person shall furnish or put in use any gas meter which shall not have been inspected, proved and sealed, or any electric meter which shall not have been inspected, approved, stamped or marked, by said Superintendent of Electrical Affairs, for which service the cor-

poration owning such meters shall pay into the City Treasury the sum of 25 cents for each meter so inspected.

Section 3. "Every gas and electric corporation furnishing gas or electricity for use in the City of Norfolk shall provide and keep in and upon its premises a suitable and proper apparatus, to be approved and stamped or marked by the Board of Control for testing and proving the accuracy of gas and electric meters furnished by it for use, by which apparatus every meter may and shall be tested, on the written request of the consumer to whom the same shall be furnished, and in his presence, if he desires it, as hereinafter provided.

Section 4. "Whenever request for the inspection and test of any gas or electric meter shall be made to the Board of Control by or on behalf of the person on whose premises the meter is installed, and such person shall have paid into the City Treasury a fee of $1.00 therefor, the said Superintendent of Electrical Affairs shall be required to make an immediate inspection and test of such meter and to report the result thereof to the said Board. Should such meter be shown by such test to be correct within 4 per cent if an electric meter and to be correct within 2 per cent if a gas meter, then and in that event the meter shall be considered as standard and the $1.00 so paid shall remain in the City Treasury and the consumer shall bear the expense of said test. If, however, said test shall show the meter to be more than 4 per cent fast, if an electric meter, or 2 per cent fast, if a gas meter, which percentage of error will be registering against and to the prejudice of the consumer, the Superintendent of Electrical Affairs shall order the gas or electrical corporation forthwith to remove the same and to place instead thereof a correct meter, approved by said Superintendent as provided in Section 2, and the deposit of $1.00 shall be returned to the person requesting the inspection and test, and said inspection fee shall be paid in to the City Treasury by the corporation owning said meter; should the meter be registering more than 4 per cent slow, if an electric meter, or 2 per cent slow, if a gas meter, then, in that event, the fee of $1.00 shall be borne by the party requesting the inspection.

Section 5. "All bills against the corporations owning gas or electric meters for inspection fees shall be reported to the Board of Control, who shall cause warrants for collection to be made out against said corporations for the said amounts.

Section 6. "Any person, firm or corporation who shall violate any provision of this ordinance, or fail to comply with any order of the said Superintendent to remove a defective meter and place instead thereof a correct meter, as provided for in Section 4 of this ordinance, shall pay a fine of not less than $1.00 and not more than $10 for each offense, and each day's continuance of such violation or failure to comply shall be deemed a separate offense.

Section 7. "This ordinance shall be in force from and after its passage and due publication, and all ordinances or parts of ordinances in conflict herewith are hereby repealed."

Adopted by the Common Council, March 4, 1913.

Adopted by the Board of Aldermen, March 11, 1913.

Approved by the Mayor, March 19, 1913.

In effect, March 29, 1913.

R. E. STEED, *City Clerk.*

WISCONSIN

Your Committee was in session at Milwaukee the latter part of April, during which time the Wisconsin Railway Commission held a hearing on the revision of the rules for gas and electric service. Upon the invitation of the Commission, your Committee attended this hearing and joined in the discussion. While the Wisconsin Commission has not yet issued its revised rules it undoubtedly will do so in the near future.

NEW YORK

The Committee received the following communication relative to recent action by the Public Service Commission of the First District, New York:

"The Public Service Commission of the First District, New York, is, as far as can be learned, the first body having jurisdiction over metering matters to definitely outline a policy for periodic testing. The Commission fixed the periods between testing after a careful investigation and hearing, at which, in addition to their own engineers, the representatives of all the electric supply companies were present and the ruling of the Commission in this matter has been accepted by the companies.

"The following is the schedule of routine periodic tests adopted:

Modern Type Alternating-Current Induction Meters

All single-phase induction meters, 2-wire or 3-wire up to and including 25 amperes rated capacity, to be tested once in 30 months.

All single-phase induction meters, 2-wire or 3-wire, over 25 amperes rated capacity, to be tested at least once in 24 months.

All polyphase induction meters up to and including 150 amperes to be tested at least once in 24 months.

All polyphase induction meters over 150 amperes rated capacity to be tested at least once in 12 months.

Continuous-Current Commutator Type Meters

All continuous-current commutator type meters, 2 and 3-wire, 110 or 220 volts, up to and including 25 amperes rated capacity, to be tested at least once in 18 months.

All continuous-current commutator type meters, 2 and 3-wire, 110 to 220 volts, 25 to 500 amperes rated capacity, to be tested at least once in 12 months.

All continuous-current commutator type meters, rated at 500 amperes and over, to be tested at least once in six months."

Respectfully submitted,

Committee
W. H. FELLOWS, *Chairman*
P. H. BARTLETT
C. G. DURFEE
F. A. VAUGHN
W. L. WADSWORTH

DISCUSSION

MR. JOHN C. PARKER, Rochester, N. Y.: Mr. Chairman, the report of the Meter Committee is such a condensed piece of strong meat that one is likely, in looking it over, to miss some of the good points, and, perhaps, to omit the one criticism that might be made on it. That criticism is due primarily to the state of the art, and not to the labors of the Committee. It lies in the fact that the report has but little to say on the subject of demand meters. It is obvious that we are up against a rather absurd condition when we are striving for a tremendous degree of accuracy in kilowatt-hour meters, while practically all of the companies make rates based more or less arbitrarily on the

solicitor's look at the customer's installation, or an estimate of the connected load from this, that and the other thing, which will vary the rate itself by 10 to 20 per cent. With such a condition, 1, 2, 3 or 4 per cent of inaccuracy in a kilowatt-hour meter becomes rather an absurdity.

Now, we find ourselves in a position where the Committee is able to report but three types of demand meter, which is really equally important with the kilowatt-hour meter. All three types named seem to be subject to some criticism, and that is perhaps what might be expected in the early stage of the maximum demand meter in the industry. The first type, unfortunately, does not give a direct record of demand, requiring more or less clerical attention in its interpretation, and does not show the consumer what he is doing from hour to hour, nor at any time during the month. One other difficulty, it seems to me, must always obtain with a meter of the type first described. With say a half-hour demand interval, the meter will have to make, infallibly and regularly, 1440 contacts during the month, and if you are a lightning calculator, you may multiply that by 12 to get its annual performance, something more than 16,000 contacts in a year. It is inconceivable that any form of contact-making device should not at some time or other during its annual performance, fail to work. If such a meter does make a miss-stroke at a time when normal load is placed on the system by the customer, no great difficulty arises. The meter in such a case would run for that hour, recording something like double what the consumer's maximum demand really should be, and the clerical force will catch that; but if the miss happens when the customer is carrying something like 60 per cent of his normal maximum demand, the meter will record 120 per cent of what the normal maximum demand is, and the clerical force will very likely let that pass. Not so the customer, however, and then trouble comes, and a lack of confidence in metering devices.

The second type of meter described seems to get away from that difficulty excellently. Unfortunately, however, it is an indicating device. The integrating meter reading is taken, and in case of dispute, one can always compare the last record reading and the reading at the time of dispute, and arrive at a fairly reasonable settlement with the customer. That does not seem to be the case with this second type described, the Westinghouse

pe. It, however, does seem to be a very excellent device otherwise.

The third type, the curve-drawing type, is rather difficult in that it requires more skilled clerical effort in interpretation, and has more or less arbitrary rules as to its use at intervals, for measuring the demand.

It is quite apparent from the ground that the report has covered that an absolutely important part of the meter industry, one which controls our gross revenue and equitable charges for service to our customers, leaves a great deal to be desired. If some manufacturer can give us an instrument that will print a record that can be taken away and filed for reference in the company's office for two or three months after the demand has occurred, which does not depend for its permanent accuracy on the non-failure of contact-making devices, and which will give some time duration to the demand, instead of being instantaneous, we shall come very close to where we should be on this demand feature in metering.

I wish to introduce these considerations into the discussion in the hope that they may encourage or stimulate manufacturers who are developing demand meters, and also indicate what one, at least, of the operating companies is looking to the manufacturers for.

MR. F. G. VAUGHEN, Schenectady: It has always been my custom to congratulate the meter committee on the work that it has done in the past year. It is only necessary to read the report to see that this committee has been active. During the past three or four years they have done exceptionally fine work. There is no question in my mind that they have greatly assisted the operating companies of the United States by issuing the Meterman's Handbook, a most excellent publication. The committee is all the time giving great assistance to the manufacturers. It attempts to help us in standardization, a thing which is necessary to secure the best results in manufacturing. The specifications given in this report covering meter registers are something which we, of the General Electric Co., are very glad to have. Unquestionably, to some of the operating companies it will appear somewhat complex at first sight, but, I think, they will find that it will eliminate a great deal of confusion in taking meter readings and making bills.

My statement in reference to standardization also applies to diagrams. I think the step taken on the part of the committee is excellent. A great deal of trouble is due, particularly in connection with polyphase installations, to the various methods used by different manufacturers in drawing their diagrams, and in having the meter properly connected in the circuit.

I have listened with much interest to Mr. Parker's comments on the maximum demand indicator proposition. However, I do not feel that I am in a position to say anything definite on the subject, although I appreciate fully Mr. Parker's views. There seems to be to-day an urgent demand for a suitable maximum demand indicator. However, the proposition has been far more difficult than appears from the name. It is, in fact, a very difficult proposition, there are many phases of it, and it is a question what they should actually accomplish. While we appreciate the fact that in the last six months to a year the operating companies have come more nearly into line in their opinions and comments, there is still a certain difference of opinion, confusion still exists. This morning I have talked with three gentlemen here at the convention on the maximum demand indicator situation, and no two of them agree. Until opinions become fixed and demands more uniform than those of to-day, it will still be a problem as to what can actually be produced in the way of a device to meet the situation.

THE CHAIRMAN: I understand that Mr. Wilder, the electrical engineer of the Public Service Commission, First District of New York, is here. If he cares to say a word to us on this subject, I would be very glad to welcome him, and to offer him the privilege of the floor.

MR. CLIFTON W. WILDER, New York City: I have nothing to say, Mr. Chairman, except that I note what the committee has stated in regard to co-operation with the Commission in the matter of meter rules and so forth. We have depended very largely, in formulating our rules, on the information obtained from and given us by the companies in the city of New York, and, I think, the spirit of co-operation has proved extremely beneficial to both the Commission and the companies. The companies have always been free to come into hearings whenever rules were under consideration, and to state very frankly what they thought these should cover, and, in that way, we have for-

ulated rules, some of which are quoted in the Committee's eport. I think that wherever there are Commissions with jurisiction, co-operation of this kind will prove very beneficial to oth parties.

THE CHAIRMAN: Is there to be any further discussion on his subject, gentlemen? If not, we will proceed to the next report, that of the Committee on Grounding Secondaries, Mr. Blood, Chairman.

MR. W. H. BLOOD, JR., Boston: This committee report is nore or less in the nature of a hardy perennial, but, I think, his year it has reached its maturity, and it is time to cut.

REPORT OF THE COMMITTEE ON GROUNDING SECONDARIES

For the past six years the Committee on Grounding Secondaries has put forth its best efforts to arouse public sentiment as to the desirability of grounding secondaries, and has persistently endeavored to secure a modification of the National Electrical Code so as to make grounding a definite requirement for all wiring installations.

At the start, opposition was encountered from many of the electric lighting companies, the claim being made that grounding secondaries was an unnecessary expense; that the idea was inconsistent with the rules of the Code, for it required all wires to be thoroughly insulated and then one of them deliberately connected with the ground from which, at considerable expense, it was elsewhere insulated; that a permanent ground put an extra strain upon the system and made it more likely for transformers and meters to burn out.

The Underwriters originally took the position that the grounding of secondaries was primarily a protection to persons rather than to property, and that if a rule were inserted in the Code requiring the grounding of secondaries, they would have no way of enforcing it.

Some municipalities operating their own water supply systems and a few privately owned water works companies objected to the attaching of electric lighting wires to their piping systems, fearing that electrolysis might follow, thus weakening the piping systems, causing constant loss of water and also making it impossible to safely furnish high pressure at times of fires.

A Committee of the American Institute of Electrical Engineers appointed to consider this same subject, while agreeing in principle with the Committee of the National Electric Light Association, originally wished to include the mandatory grounding of circuits carrying as high as 250 volts.

As the result of various conferences, by a large amount of publicity work, and by the personal efforts of the members of your Committee, an almost unanimous opinion now prevails with regard to the desirability of grounding secondaries.

The electric lighting companies now fully realize that by grounding secondaries their customers are protected from fatal shocks due to line troubles or faulty transformers. The expense of grounding secondaries has been shown to be slight and well worth taking, in that it prevents serious and fatal accidents, thus saving the company from lawsuits and financial losses. It has also been proved by the records of the companies that there is no extra burden placed upon meters and transformers because of grounded secondaries. The companies find, however, that to ground old wiring installations which are already partially grounded is not good practise, and that it is necessary first to clear up the insulation of old wiring jobs, thus making them safer from every standpoint and materially reducing the fire risk, as well as providing a reliable protection against injurious or fatal shocks.

The Underwriters' organization was broadened about two years ago and the revision of the rules of the National Electrical Code became a function of the Electrical Committee of the National Fire Protection Association. This Committee includes representatives from all of the national electrical associations and because of this make-up is able to recognize the life hazard as well as the fire hazard, and thoroughly approves of the mandatory grounding of secondaries.

The municipal authorities now largely agree that in the making of wiring rules it is fully as important to see that life is protected as that property is protected, and they appreciate that the grounding of secondaries is the most satisfactory method yet suggested for keeping out of buildings high potential and dangerous currents. It is well recognized by those who have studied the subject, that the connecting of secondary alternating-current systems to water pipes does not produce any additional burden upon the piping systems. It has also been proved conclusively that an alternating-current does not produce electrolysis.

While it is believed that the Committee of the American Institute of Electrical Engineers still adheres to its former opinion that grounding should include 250-volt circuits, the Committee of the National Electric Light Association does not agree that this procedure is always wise. A compromise as to the voltage

which should be specified was effected between the Committees, the recommendation of the joint Committees being to make the rule mandatory to ground circuits up to 150 volts and to leave it optional above that voltage. The National Electric Light Association Committee believes that this is a satisfactory solution, for it covers, with very few exceptions, all of the lighting installations in the country, and so protects practically all users of electric light. As the wiring of 250-volt circuits applies almost entirely to motor installations, which are generally constructed with more care and as motors are ordinarily under more expert supervision, it is believed that the liability to accidents on these circuits is not large. The exact wording of the rule as it will appear in the Code was referred back to a Committee of the National Fire Protection Association. This Committee has not as yet made its final report, so that at the present moment it is impossible to present the wording as it will appear. The principal point, however, is that the new rule will contain the provision that circuits in which the maximum difference of potential between the grounded point and any other point does not exceed 150 volts *must* be grounded, and that when the maximum difference of potention between the grounded point and any other point exceeds 150 volts it *may* be grounded.

The Committee's recommendation to all member companies is that they anticipate so far as possible the enforcement of this rule. The Committee also wishes particularly to emphasize its conviction that a poor ground connection is very undesirable and may, under some conditions, be worse than no ground at all. The Committee firmly believes that a ground connection made to a complete metallic underground piping system is the best that can be secured and that the best practise is to ground each service at a point where it enters the building. Another method, equally satisfactory where many customers are served in a limited area, is that of running a neutral ground wire upon the pole line, connections being made to the ground through metallic underground piping systems at all substations and at other places where such piping can be reached. The modified rule in the Code permits other methods under different conditions, but they are to be utilized only when a metallic piping system is not available.

The Committee believes, by securing the adoption of this rule by the National Fire Protection Association, that it has ful-

filled its mission, and, therefore, recommends the acceptance of this report and the discharge of the Committee.

Respectfully submitted,

Committee
W. H. BLOOD, JR., *Chairman*
W. C. L. EGLIN
H. B. GEAR
W. T. MORRISON
PAUL LINCOLN*

DISCUSSION

THE CHAIRMAN: Gentlemen, this report is before you for discussion. It is not within the province of this meeting to act on the request of the Committee that it be discharged, but it might be well to have an expression of views from some of the members as to whether they think it important that this special work should be continued.

MR. H. B. GEAR, Chicago: Mr. Chairman, I move you that it be the sense of this conference and that we recommend to the Executive Committee that this Committee on Grounding Secondaries be discharged.

MR. WM. C. L. EGLIN, Philadelphia: I would like to amend that by having it read, that the report be accepted and the Committee discharged.

MR. GEAR: I will accept that.

(The motion as amended was duly seconded and carried.)

THE CHAIRMAN: The next number is the Report of the Lamp Committee, Mr. Frank W. Smith, Chairman.

MR. FRANK W. SMITH, New York City: I believe I cannot do better than present this, the Report of the Lamp Committee, in abstract as printed in the front part of the paper. Your Committee, hopes, however, that the members will find an opportunity to read the report through and that it will be found helpful in some directions and furnish useful information concerning this important branch of our business—the incandescent lamp.

On behalf of the Committee I desire to acknowledge with thanks the co-operation of the lamp manufacturers and others who were helpful in the preparation of this report.

*Not signed by Mr. Lincoln, as he was travelling in the West when the report went to print.

REPORT OF THE LAMP COMMITTEE

The work of the Lamp Committee during the past year has been principally confined to the collection of data and the preparation and publication in the Association monthly *Bulletin* of articles covering the various phases of the incandescent lamp situation, the committee carrying out in this respect the recommendations embodied in the report submitted at Seattle in 1912.

Articles have so far appeared in the *Bulletin* on the following subjects:

"The Passing of the High-Wattage Carbon and Gem Lamps"......September, 1912
"The Increasing Importance of Sign Lighting" ....February, 1913
"The Mazda Lamp in Residence Lighting" ....March, 1913
"Incandescent Lamp Developments Since the Last Lamp Committee Report".......April, 1913

Your Committee has felt that the best interests of the member companies would be served by this method of disseminating information throughout the year rather than by holding the data for presentation at the annual convention.

This report will, therefore, not concern itself particularly with the details already covered in these various articles, but for ready reference the articles are reproduced herein in full as an appendix. Such additional information as would seem to your Committee to be of interest at this time is herewith presented.

LAMP SALES

In the 1912 report the total sales of lamps of all types for domestic use was stated to be in round figures eighty-five million (85,000,000). During 1912 changes in the method of reporting sales by the manufacturers prevent an accurate determination of such sales, but in round figures the total sales aggregated approximately ninety million (90,000,000) lamps. This is an increase since 1907 of 41.7 per cent and for the year 1909, 20.09 per cent; 1910, 12.40 per cent; 1911, 8.45 per cent; and 1912, 5.87 per cent.

The committee again presents a table, including the year 1912, showing the extent to which lamps of the different types

(carbon, gem, tantalum and mazda) contributed to the total output during the period from 1907 (the advent of the mazda lamp) to 1912, inclusive:

DOMESTIC INCANDESCENT LAMP SALES 1907-1912, INCLUSIVE, SHOWING PERCENTAGE OF CARBON, GEM, TANTALUM AND MAZDA TO TOTAL

Type	1907 Per Cent	1908 Per Cent	1909 Per Cent	1910 Per Cent	1911 Per Cent	1912 Per Cent
Carbon	93.27	84.12	68.98	63.08	52.90	25.47
Gem	5.88	8.58	15.07	14.88	19.00	33.59
Tantalum	.75	1.78	2.12	3.57	2.74	1.00
Mazda	.10	5.52	13.83	18.47	25.30	39.94
Total	100	100	100	100	99.94	100

Last year the Committee predicted that for 1912 the output of the carbon lamp would be reduced to about 20 per cent of the total sales. The actual figure, as indicated, was 25.57 per cent, a marked reduction over 1911, with an offsetting increase in the output of the gem-metallized and mazda, the sales of the carbon lamp dropping to less than 50 per cent of the output for the previous year (1911). It is reported that orders received by the lamp manufacturers for the past few months indicate that the sales of the carbon lamp during the present year (1913) will be less than 10 per cent of the total output.

The output of gem-metallized filament lamps increased from 19 per cent to 33.59 per cent during the past year, while the mazda lamps increased from 23.36 per cent to practically 40 per cent of the total output. This shifting of demand from one type of lamp to another during the past six years, as indicated in the following table, is more graphically shown in the curve herewith, which is a reproduction of the curve shown in the last year's report extended for another year, so as to include 1912.

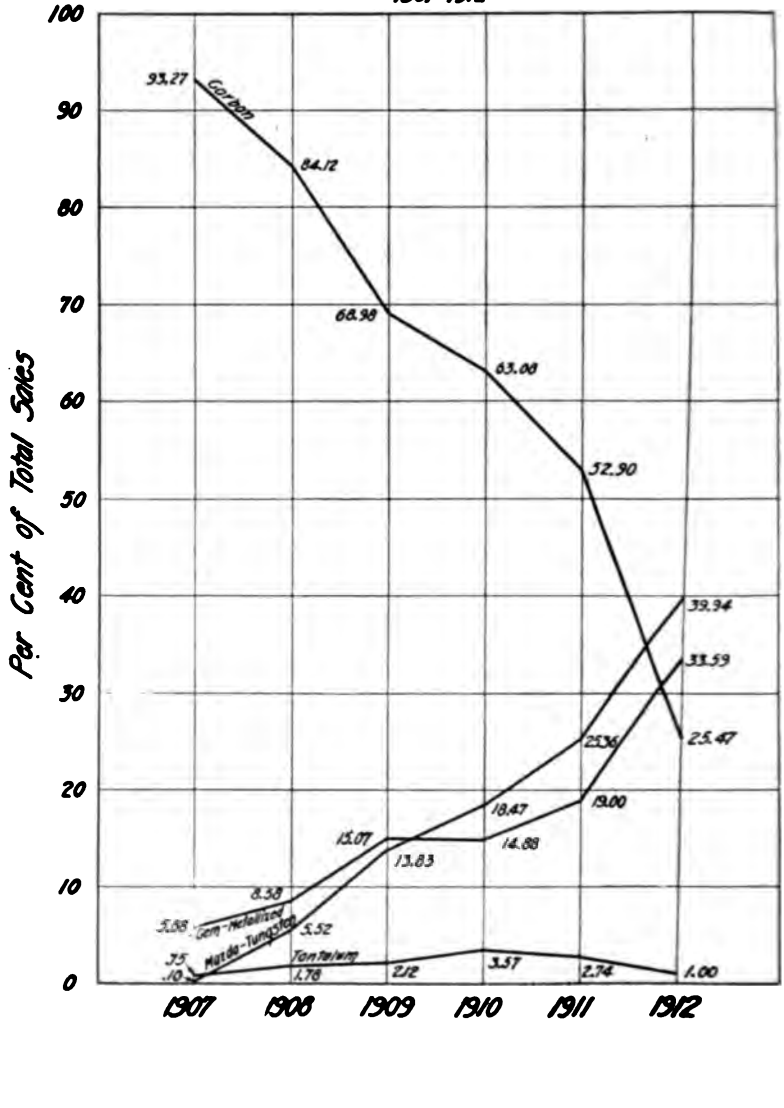
The output of the tantalum lamp during the past year has been further reduced, and is now a negligible quantity, representing in the aggregate practically the same volume of business as in 1907, six years ago, when this type of lamp was first introduced.

The Lamp Committee in its report last year earnestly recommended to all member companies, both small and large, the adoption of the gem-metallized lamp in substitution of the carbon lamp.

Curves Showing Yearly Sales of

Domestic Incandescent Lamps

1907–1912



That this practise has been adopted to a very marked degree is recorded in the increased demand for gem-metallized lamps during 1912, the sales for the past year showing an increase of 75 per cent over 1911. Under the prevailing conditions there would seem to be no reasonable excuse for failure on the part of member companies to adopt the gem-metallized filament lamp in substitution of the carbon lamp, and your committee repeats its recommendation of last year in that respect.

In this connection it is interesting to point out that under date of February 1, 1913, the Treasury Department of the United States Government issued an order covering instructions for the use of electric lamps, which set forth that after that date gem or carbon metallized-filament lamps of any description must not be used, thus adopting the mazda lamp exclusively for the purposes of the Government.

In order that it might be determined to what extent member companies had adopted the gem-metallized filament lamp, and in what respect, if any, the company policy had been changed with respect to the incandescent lamp situation generally during the past year or two, your Committee early in April caused to be sent to member companies a return post card of inquiry on the following points:

"In what respect, if any, has the policy of your company changed within the past two years in regard to lamp renewals?"

"Are you now supplying free renewals of carbon lamps?"

"Are you now supplying free renewals of gem lamps?"

"What is your present policy as to first installation as well as to renewal of tungsten lamps, and under what conditions do you supply them?"

ANALYSIS

An analysis of the replies indicates the following:

Eleven per cent of the member companies reported a change within the last year or two in their lamp policy, these changes summarizing as follows:

	No. of Companies	Per Cent
Substituted free gem lamps for carbons.........	14	3
Discontinued free renewals	13	2.5
Inaugurated free renewals	14	3
Discontinued furnishing carbon lamps...........	11	2
Reduced price on renewals (companies pursuing non-free renewal policy)	8	2

In the matter of free renewals, the following table gives the policy of the companies reporting, the percentage figures being based on the number of companies replying to the inquiry:

FREE RENEWAL

Carbon		Gem	
Yes	No	Yes	No
29%	49%	37%	58%

(The difference between the total percentages of "Yes" and "No" under carbon and gem and the total, 100 per cent, is made up by companies reporting which have discontinued to furnish carbon lamps and companies reporting as not furnishing lamps at all.)

In a few instances companies reported furnishing free renewal on commercial service and non-renewal on domestic service. In several cases free renewals are made with consumers on a flat-rate basis with non-renewal on metered service, while this policy is reversed in about an equal number of cases; that is, free renewals are furnished in the case of metered service, with non-renewal on flat-rate customers.

Fifteen per cent of the companies reported the discontinuance of the carbon lamp.

Four per cent reported that they are not supplying lamps at all.

In several cases gem lamps are furnished in the higher wattages, while carbons are supplied for lower wattages.

Several companies reported very unfavorable experience with gem lamps.

The policy of the companies reporting as to the first installation and renewal of mazda lamps and the conditions under which they are supplied is indicated in the following summary:

	No. of Companies	Per Cent
Mazda lamps furnished at list price, both first installation and renewal	283	58
Mazda lamps furnished at a small profit	57	11
Mazda lamps furnished at cost	83	17
First installation purchased by customer, renewal at cost, less price of carbon or gem	11	2
First installation at list price, allowance on renewals of from 10 to 15 cents	10	2

In a few cases the first installation is given free and renewals at cost, and in one or two cases where the first installation is furnished free a small allowance is made on renewals, while in one

case the first installation is charged for and renewals are supplied free.

About 5 per cent of the companies reporting do not supply mazda lamps, this type of lamp being furnished by dealers.

A number of companies report that they are furnishing the higher wattages free on both first installation and renewals, that is, the 250-watt, 400-watt and 500-watt mazdas.

Your Committee is of the opinion that it would be profitable to investigate further some points brought out by these replies. For instance, it would be interesting to know the conditions which prompted 13 companies to discontinue the free renewal policy while 14 reported inaugurating a free renewal system.

It would be well to ascertain why a large percentage of member companies still refrain from adopting or recommending to their customers the gem-metallized lamp. Also to learn in what respect the gem-metallized lamp is at this late date reported by several companies as having proven unsatisfactory.

DEVELOPMENT

The past year has witnessed a more rapid development in the tungsten-filament lamp than previous years. The pressed-filament lamp has been abandoned by all of the large American manufacturers and they have universally adopted the use of drawn tungsten wire. Working in conjunction, they have adopted the same general design, and their united efforts are resulting in more marked advance in the art of incandescent lamp manufacture. The improvements and economies in manufacturing processes during the year have enabled the manufacturers to put into effect reduced schedules of prices on the mazda lamps. Developments have also improved the quality of the lamp and a constant increase in efficiency has been possible, while the life of the lamp has been maintained compatible with the life most suitable for commercial service, and that guaranteed. With improvements which seem likely to be realized in the near future, it may be practicable to make further advancement in efficiencies without material sacrifice of life.

In the Committee's report of last year reference was made to marked improvement in the quality of high-wattage mazda lamps of 250 watt and above. During the past year this improvement has been extended to the 150-watt and 100-watt lamps.

ELECTRIC SIGN LIGHTING

This subject is treated rather fully in one of the articles published during the year and appended herewith.

The development of the electric sign business has continued during the year and central-station companies very generally report a marked increase in sign business.

Very satisfactory results are being obtained by the use of special tungsten-filament lamps for this service, and all of the larger lamp manufacturers report a marked increase in the output of the sign lamp.

Your Committee feels that the member companies will do well to address themselves to this branch of the business as presenting attractive possibility for increased output.

NEW TYPES OF LAMPS STANDARDIZED

Since May 1, 1912, a number of new types and sizes of lamps have been standardized and announced by the manufacturers as additions to their regular schedules. These new types of lamps are as follows:

TUNGSTEN FILAMENT LAMPS

REGULAR SERVICE

10-watt 100-130 volt S-17 bulb
40-watt 100-130 volt S-19 bulb
60-watt 100-130 volt S-21 bulb

SIGN LAMPS

5-watt 60- 65 volt S-14 bulb
10-watt 100-130 volt S-14 bulb

DECORATIVE SERVICE

15-watt 100-130 volt B- 9 bulb
15-watt 100-130 volt D- 9½ bulb
15-watt 100-130 volt T- 8 bulb
15-watt 100-130 volt G-16½ bulb
15-watt 100-130 volt P-12½ bulb

SERIES BURNING RAILWAY SERVICE

56-watt 100-130 volt S-21 bulb
94-watt 100-130 volt S-24½ bulb

HEADLIGHT AND STEREOPTICON SERVICE

100-watt 100-130 volt G-30 volt

In addition to the above, a complete line of 6 and 7-volt tungsten-filament lamps, suitable for automobile lighting service, has been developed and is being regularly and successfully marketed, the manufacturers reporting a considerable business along this line.

TRADE NAME "MAZDA"

The name "mazda" has now been adopted by all of the larger domestic manufacturers covering the tungsten lamp field.

POPULARIZING THE MAZDA LAMP

The central-station companies have continued a broad and liberal policy with respect to the introduction of the tungsten-filament lamp, and manufacturers generally have co-operated one with the other and with the central-station companies in publicity campaigns. They have widely advertised the merits and advantages of the high-efficiency lamps.

The electrical shows throughout the country, which are now rather widely recognized as an annual feature, are being liberally supported for the exhibition and exploitation of the improvements in high-efficiency lamps. All of this publicity must have its effect upon the purchasing public and be an influence toward the more general adoption of the mazda lamp.

The Committee feels that it may well repeat the recommendations contained in the previous report of a liberal policy by central-station companies to encourage the adoption of the mazda lamp by its customers.

It is felt that the policy should be continued by the incoming Lamp Committee of utilizing the Association BULLETIN for the publication of frequent articles with respect to lamp development. Through this medium full and detailed information can reach the members promptly. The Committee is informed by the Secretary of the Association that there has been a general demand among the membership for BULLETINS containing articles published by the Lamp Committee. The articles are now reprinted herewith as an Appendix.

It is fitting that the Committee should here give expression of its appreciation to those who have kindly and ably assisted in the work throughout the year and in the preparation of this report.

Respectfully submitted,

Committee
- FRANK W. SMITH, *Chairman*
- W. W. FREEMAN
- WALTER H. JOHNSON
- GEORGE F. MORRISON
- F. S. TERRY
- WALTER CARY
- H. B. GEAR

THE PASSING OF THE HIGH-WATTAGE CARBON AND GEM LAMPS

The report of the Lamp Committee, submitted at the Thirty-fifth Convention in Seattle, June 10-14, in commenting on the development of the tungsten lamp of higher units states as follows: "Very recently a marked improvement in tungsten lamps of 250, 400 and 500-watt, of 100 to 130-volt, has been made, permitting the standardization of these lamps at an efficiency of one watt per candle, while attaining a useful laboratory life of approximately 1000 hours with good maintenance of candle-power, and it would seem that these higher candle-power units should find a more general field of usefulness."

The percentage of high candle-power carbon and gem lamps in use to-day is very small as compared with the total output of lamps, and it seems evident that this small number will rapidly disappear.

As set forth in the Committee's report, the present high-efficiency drawn-wire filament tungsten lamp shows particularly great superiority over the carbon and gem in the higher candle-power sizes, and has so far decreased the output of the larger sizes of the lower-efficiency lamps that the lamp manufacturers have discontinued the listing on the price sheets of these lower-efficiency lamps in the larger units.

The largest gem and carbon lamps now regularly made and listed by the manufacturers give about 40 candle-power, consuming 100 watts in the case of the gem, and 120 watts in the case of the carbon.

The manufacturers report that the demand for the gem and carbon lamps in these larger sizes is now almost entirely filled by the tungsten filament lamp, on which the mechanical breakage of the filament is reported as being extremely low. The objection formerly raised to the fragility of the metallized-filament lamps seem to have been practically removed through the improvement in the filament manufacture and form of construction. The Committee's report deals briefly with these improvements.

It is now well known and generally conceded, that the drawn-wire tungsten-filament lamps of all sizes are capable of withstanding the requirements of ordinary service and burning

in any position; the strength of the filament of the larger unit is greater than that of the smaller.

In the discussion which took place at Seattle, following the presentation of the report of the Lamp Committee, Mr. John W. Lieb, of New York, stated with regard to these higher candle-power units of the tungsten-filament as follows: "Of interest, of course, will be the manifest improvement not only in efficiency, but also in life and holding up of candle-power which has been found to be the case in the more recent product of the larger types of tungsten lamps—100-watt, 250-watt and larger lamps. The effect which the perfection of these larger sizes of lamps of improved efficiency, long life and holding up of candle-power will have in displacing the old forms of carbon enclosed lamps it is hardly possible to prophesy. . . . The improvements referred to, and other improvements which are under way, should open up a very profitable field (incandescent street lighting) for central-station industry."

Mr. John W. Howell, of Newark, in discussing the Committee's report, said, with respect to these larger units of the tungsten-filament type: "The paper speaks of the very excellent results which have been achieved with 250, 400 and 500-watt tungsten lamps. The gem lamp has no substitute for these, but with the lower sizes of lamps, the 100-watt, for instance, and the 150-watt lamps, which are made excellently in the tungsten, in the gem they are not good, comparatively speaking. I would recommend that the larger sizes of gem be not used, but that they be replaced with the 100-watt or 150-watt tungsten lamp."

It would seem that the replacement of high-wattage carbon and gem lamps by tungsten-filament lamps should be encouraged so far as possible. The advantage to the customer is apparent. The increase in illumination obtainable by the consumer substituting the same wattage in tungsten for carbon or gem is of considerable moment, so that the increase in the cost of the lamp, which increase it is reasonable to assume will gradually diminish, is more than offset by the increased illumination and better quality of light. As a matter of fact, the tungsten-filament lamp will give about double the illumination at a relatively small increase in total cost (about 13 per cent).

With the adoption of the present type of drawn-wire tungsten-filament lamps, satisfactory performance is well assured.

Many of the central-station companies are advocating to their customers the replacement of gem and carbon lamps of larger units by these high-efficiency tungsten-filament lamps, and it would seem that the member companies can best serve their customers by bringing to their attention these advantages, or, as the Committee recommended in its report:

"Your Committee feels that it should at this time again urge the member companies to follow a broad and liberal policy with their customers in order to encourage the adoption and use of the mazda lamp. Those companies which from the first introduction of the high-efficiency lamps offered them to their customers on favorable terms, with an aggressive campaign for new business, reaped their reward early, as any temporary loss that may have been felt in revenue was soon more than offset by the addition of new business, longer hours of burning and better satisfied customers."

THE INCREASING IMPORTANCE OF SIGN LIGHTING

In the report submitted by the Lamp Committee at the Seattle Convention, under the heading "Electric Sign Lighting" (see Volume III, pages 314-29, 35th Convention *Proceedings*) information was furnished in more or less detail as to the increasing importance of sign lighting, made possible by the development on the part of the manufacturers of the mazda-tungsten sign lamp. In Volume II, pages 191-93, of the 35th Convention *Proceedings,* the report of the Committee on Electrical Advertising and Decorative Street Lighting stated that there were at that time installed in the United States and Canada approximately 80,000 electric signs, containing 8,000,000 lamps. Since that time the increase in sign lighting has been very marked, and this branch of the electric lighting industry has, therefore, grown to such proportions that it demands earnest and careful consideration by every member company. The electric sign business is not only profitable, but most desirable on account of the publicity given to the use of electric lighting, and many central-station companies, recognizing the importance of this business, are seeking to increase and improve this desirable load.

The development of the electric sign is naturally very closely allied with the development of the incandescent lamp, in fact, the success of an electric sign depends to a marked degree upon

the selection and use of proper lamps. Any improvements, therefore, which are made on sign lamps may rightly be considered as improvements on the sign, and as such go to help the industry.

The Lamp Committee desires at this time to again bring before the member companies the recent improvement and development made by the manufacturers in sign lamps, which improvements will undoubtedly be of material assistance to those companies desirous of increasing their electric sign business.

Prior to the year 1910, the 10 and 20-watt carbon lamps were the only sign lamps available. They were then, as now, rated at an efficiency of practically 5 watts per candle. As it was found extremely difficult to get new business with these lamps, there was a crying need for more efficient sign lamps. At about this time the 2½ and 5-watt 10 to 13-volt lamps were developed and immediately became popular. Since this type of lamp contained a squirted tungsten filament, it was necessary to make it a low-voltage lamp in order that it might be rugged enough to withstand successfully the severe conditions of sign service. As the 10 to 13-volt range, in addition to insuring a more rugged lamp, was also convenient transformation ratio, it was used.

The discovery of the process of drawing mazda-tungsten wire has undoubtedly been responsible for many improvements in this type of lamp. Among other things, it is now possible to draw the wire very fine, and, at the same time, down to exact diameters. This has made possible a closer selection of all lamps, which is of particular importance with the 10 to 13-volt sign lamps when operated in series. The fact that the use of the drawn wire has made a more rugged lamp, has worked to the advantage of the sign business. The manufacturers state that any and all sign lamps of recent manufacture can be used indiscriminately in either multiple or series work. The most recent development has resulted from the drawn wire in the 10-watt 100 to 130-volt, and 5-watt 50 to 65-volt sign lamps. These lamps are a welcome addition to the mazda-tungsten lamp schedule, and will undoubtedly be of material assistance to central-station companies, especially those supplying direct current.

Since the series system of wiring on 10 to 13 volts has certain disadvantages, and has not been entirely successful, particularly with the earlier types of lamps, due largely to inherent defects in the system of wiring, these lamps made in higher voltage ranges

are a decided improvement. The 10-watt lamps may be wired in multiple in standard voltage, and will unquestionably lead to much new business. The 5-watt 50 to 65-volt lamp may be used by wiring two lamps in series. The results from the use of this lamp should be nearly as good as from the 10-watt lamp wired in multiple. For alternating-current circuits the 2½-watt and 5-watt lamps are desirable where lower wattage is required.

Although there are a number of 10, 20, and even 30-watt carbon sign lamps in use to-day, the nature of the sign business demands lower wattage lamps. The installation of a sign equipped with the modern low-voltage lamps will soon displace the old type of sign.

The cost of operating a low-voltage mazda-tungsten lamp is so small that every merchant can afford to install a representative electrical sign. The income on a lamp hour basis for mazda-tungsten lamps may not be as high as that from the carbon, yet the total revenue from this class of business will be greater, due to the fact that the more modern lamps make it possible to obtain many new customers who could not be induced to use carbon lamps. That this has worked out in practise is evident from the marked increase in the sign business throughout the country. Particularly is this true in cities where central-station companies have conducted an aggressive campaign in co-operation with the electrical sign and lamp companies. When a customer changes from carbon to mazda-tungsten, the decrease in operating cost will induce the merchant to burn the sign longer, thereby securing greater publicity and advertising from his original investment without much, if any, additional cost for the current.

Briefly, therefore, the mazda-tungsten lamp should make for an increase in the number of customers and in the load-factor of the old customers. The experience of the central-station companies which has given the mazda-tungsten lamp a trial has proved that, in addition to these gains, it has led to an increase in the net revenue. This is true not only of the sign business but of the introduction of the mazda-tungsten lamp in general.

Some central-station companies include in the active sign campaign a maintenance service. In certain localities merchants are apt to neglect or are unwilling to properly maintain their signs, the result being an untidy sign and a dissatisfied customer.

The local conditions, however, should control the policy of the central-station company in this regard. Where sign manufacturers are fully equipped to undertake and maintain signs, this branch of the work should be left to them. If this is not practicable the central-station company might find it advantageous to take this important work upon itself, and establish a sign maintenance bureau, through which this business could be properly cared for.

The Lamp Committee will be glad to furnish member companies with information as to methods used and results obtained by some of the central-station companies which are seeking to build up this very desirable electric sign business with the newer and improved low-voltage mazda-tungsten sign lamps.

THE MAZDA LAMP IN RESIDENCE LIGHTING

The Lamp Committee has forwarded the subjoined matter to the *Bulletin* for publication.

"In all branches of central-station practise so many developments have taken place within the last few years that some have received much less attention than their real importance would warrant. Thus it is that, although the average station has probably given a good deal of thought to the improvement of its residential lighting service by the use of high-efficiency lamps, very little systematic effort has actually been put forth to bring about such a change.

"The mazda lamp is not an experiment in any sense of the word. The standard line includes a variety of sizes, in both straight side and round bulbs; and even candelabra decorative lamps are now available in the standard voltage range. The lamps will burn in any position and they are put in cartons, which makes it easy for the customer to carry them home, and convenient for him to keep a few extra lamps on hand. The efficiency of the mazda lamp in producing light is unquestioned; its mechanical strength is such that it is being used successfully under severe conditions of street railway service. Large industrial concerns have adopted it after exhaustive investigation. In business districts, where the value of the increased illumination so easily obtained with the mazda lamp was quickly recognized, it has gone into almost universal use.

"The residential customers whose installations are small and whose technical knowledge is limited are not in a position to

analyze their lighting requirements as closely as have the larger customers. They are, therefore, still using lamps that would not even be considered in other classes of service, and, in consequence, they are enjoying less than half of the illumination they could easily secure for the same expense. That this so obvious advantage could be overlooked is almost incredible. The trouble in the case of the small customer seems to lie in the fact that the initial outlay required in changing over to high-efficiency lamps assumes abnormal magnitude in his mind. Of course, such outlay is more than returned and offset by the vastly improved illumination; and the best service that a central station can render to its residential customers is to impress upon them in every possible way the fact that it is only by the use of the mazda lamp that they can obtain all that is possible for the money they spend for electric lighting.

"It is, however, hardly sufficient merely to advise the residential customer to use mazda lamps, without showing him how the best results may be secured. The proper shading of lamps is a matter of great importance in residential service, and the central-station illuminating engineering department could well supplement the efforts of the commercial department in developing and improving residential lighting. If the company has no such department good advice is easily obtainable. This work might be done, for example, by judiciously using mazda lamps for indirect or semi-indirect systems, enclosing the globes in proper shades to produce the mellow, soft effects desired by many in the home; or, where lamps are exposed to view and where some other means of shading cannot well be provided, by seeing that the lamps are frosted rather than clear. There is a good deal of room for improvement in present residential lighting, and no central station can afford to allow its residential customers to worry along with lighting service that is barely acceptable when so much can be done with the mazda lamp to raise the home standard of illumination and give a satisfactory installation."

INCANDESCENT LAMP DEVELOPMENTS SINCE THE LAST LAMP COMMITTEE REPORT

Since the report of the Lamp Committee was made at Seattle in 1912 (see Vol. III, p. 318, 35th Convention *Proceedings*) a

number of mazda-tungsten lamp developments of importance have taken place. These were along the lines of improvements in the quality of some types of multiple lamps, in the method of rating series-burning lamps and the development of new low-wattage types.

There have been marked improvements in the quality of some of the higher wattage, 100-130-volt range, and in compensator and train-lighting lamps. In the 60, 100 and 150-watt, 100-130-volt range lamps, improvements in quality have taken place similar to those reported in the case of the 250, 400 and 500-watt lamps in the Seattle report. This improvement in quality has made possible substantial improvements in efficiency. The increase in quality of the train-lighting and compensator lamps is even more marked than that of the high-wattage types.

To meet the demand for a 60-watt small-base lamp for use in residence lighting and in similar classes of illumination and to provide a 40-watt lamp that will in all cases be interchangeable with the 25-watt lamps these two types have been standardized in S-19 and S-21 bulbs, respectively. That is, the 60-watt lamp is now made in the small bulb that was standard for the 40-watt lamps, and the 40-watt in the bulb that was standard for 25-watt lamps. This change has been made without impairing the life or efficiency of the lamps, and is along the line of standardization. The new 60-watt small-base lamp being, as stated, in the size formerly used for the 40-watt, cannot be used properly with the present 60-watt reflector equipment. As a large percentage of the 60-watt lamps have been installed in combination with reflectors, and as the position of the light source in the reflector is important, the lamp manufacturers have designed a socket which is self-locking and may be used to adapt the unskirted S-21 bulb 60-watt lamp to reflectors designed for the S-24½ bulb 60-watt lamp, the combination producing the correct light distribution.

The present 60-watt reflector equipment may, however, be used with the new and smaller lamps by a change in the form of shade holder used. The form "O" shade holder may be substituted for the form "H" shade holder. By this method and the adoption of the socket extension the difficulties encountered, due to the fact that the new 60-watt lamp cannot be used properly in the standard 60-watt reflector equipment, will be taken care of. It is thought that eventually this matter will adjust itself. The

change is all in the nature of standardization on the part of the lamp manufacturers and should eventually result in price reductions.

In the old pressed filament process and in the early stage of the wire drawing process, it was commercially impossible, on account of the high price that would result from a sufficiently close selection, to make filaments of the exact amperes desired. It was necessary, therefore, in lamps intended for series burning service, to make them as nearly as possible the correct amperes, photometer them to determine the current necessary to produce the correct efficiency and then to sort them in narrow ampere ranges. Only lamps of the same ampere range were suitable to burn in series together. Extreme care was required that each customer should always receive lamps selected for his range of amperes. In cases of errors in photometry, sorting or accidental mixing, customers received lamps of widely different amperes and these, burning in the same series, naturally produced ununiform candle-power and variable lives.

Improvements in the wire drawing process have made it possible to select wire that will produce lamps of approximately exact amperage. Hence it is possible now to have, instead of a range of amperes for each size of lamps, a single current rating for each size. For instance, in the case of the 6.6 ampere, 40 c-p. street series lamp, where it was formerly necessary to have ampere ranges corresponding to 6.3, 6.4, 6.5, 6.6, 6.7, 6.8 and 6.9 amperes and always to supply each customer with lamps from a single one of these ranges, it is now possible to make all lamps of this size almost exactly 6.6 amperes. This improvement is adopted for all lamps intended for street series service and series-burning sign service, and has been productive of greatly improved results in both cases. It has also made possible the adoption of only five standard amperages for street series circuits, namely, 3.5, 4.5, 5.5, 6.6 and 7.5 amperes. It will be apparent to all central-station companies that it is now highly desirable that all street series lighting circuits be adjusted to one of these standard current values.

In addition to the above-noted improvements in the mazda-tungsten lamps, and as pointed out by the Lamp Committee in an article in the February *Bulletin*, under the title "The Increasing Importance of Sign Lighting," a 10-watt, 100-130-volt

and a 5-watt, 50-65-volt sign lamp in the S-14 bulb (1¾ in. in diam.) have been developed. A 10-watt, 100-130-volt lamp is also made in the S-17 bulb (2⅛ in. diam.) for use in residence lighting. These are very important additions to the line of sign lamps in that they furnish a low-wattage lamp that does not require the operation of more than two lamps in series even upon 200-260-volt circuits. The manufacturers report that these lamps are giving very satisfactory life performance in actual service.

The Lamp Committee will be glad to furnish any member companies such further detailed information with regard to these developments as may be desired.

THE CHAIRMAN: Before this report is offered for discussion, and I hope there will be profitable discussion, we will have a paper by Mr. J. E. Randall and Mr. E. J. Edwards on Recent Progress in the Art of Lamp Making. I regret to say that, through some unforeseen accident, the printed copies of the report have been lost, so that they are not here for distribution, and further, that Mr. Randall had desired to show some lantern slides, but, as we were not aware of that until he arrived here, we have been unable to make provision for it.

MR. J. E. RANDALL, Cleveland: I wish to mention that Mr. Edward is joint author of the paper I shall read, and has done much of the work in connection with the preparation. I regret that we have not the facilities which we had hoped would be available here for throwing certain figures on a screen. Some of the effects which we would like to bring before you this afternoon will perhaps be lost.

RECENT PROGRESS IN THE ART OF LAMP MAKING

There have been no very spectacular changes in the manufacture of regular incandescent lamps during the past year, but, nevertheless, some very important developments have taken place. Since the very beginning of the incandescent lamp industry, progress has been made which has been manifested mainly by in-

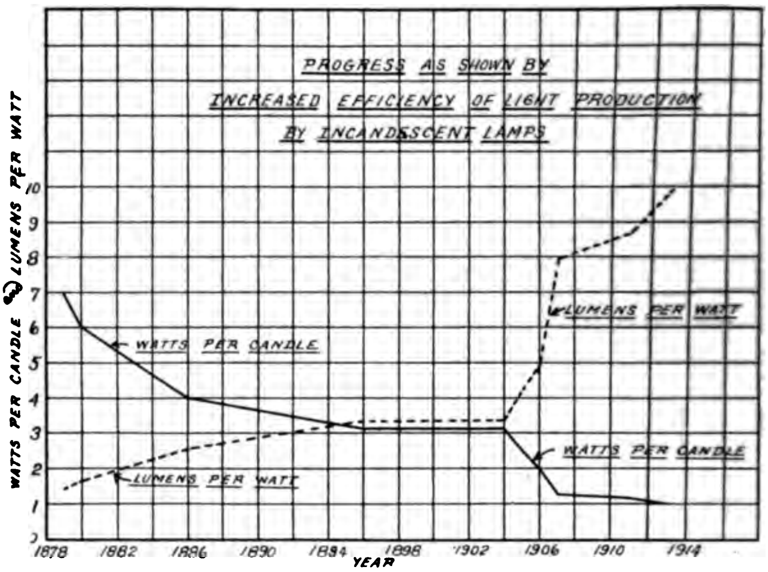


FIG. 1

creased efficiency of operation. The power required per unit of intensity has decreased from 7 watt per candle power to 1 watt per candle and the past year can claim the last increment of 0.15 of a watt in this progress. The curves of Fig. 1 show graphically the rates at which this progress has been made in terms of the more familiar unit, watts per candle, and also, in terms of the exact unit, lumens per watt.

It is of interest to note the means employed in accomplishing this latest improvement in efficiency. Every purchaser of lamps knows well that the useful life of incandescent lamps has

heretofore been determined largely by the degree of clearness maintained by the bulb over continued periods of operation. This was true of all of the early carbon lamps and also of the former tungsten filament lamps in the large sizes. In the low wattages of tungsten filament lamps of the 110-volt

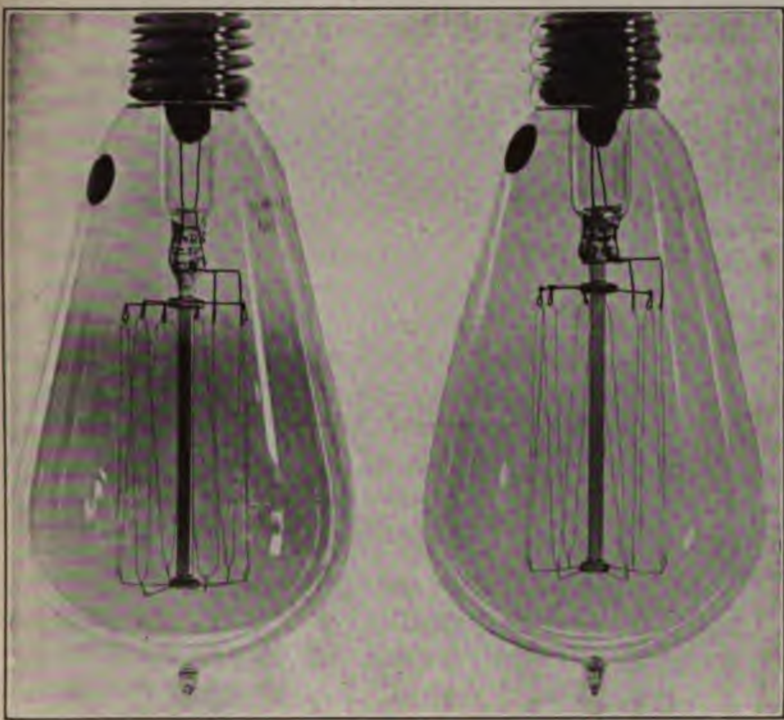


Fig. 2

class, say 25-watt and lower, the filament was so small, a thousandth of an inch or less in diameter, that the life of the lamp was determined by the ability of the filament to hold together rather than by bulb deposit considerations. It was apparent, then, that some means of preventing the black deposit upon the inner walls of the glass bulb would considerably improve the quality of the lamps using large filaments, in fact of any lamp

whose useful life was limited by bulb blackening rather than by filament failure.

After a long series of laboratory investigations, the lamp manufacturer found that the introduction of certain chlorides

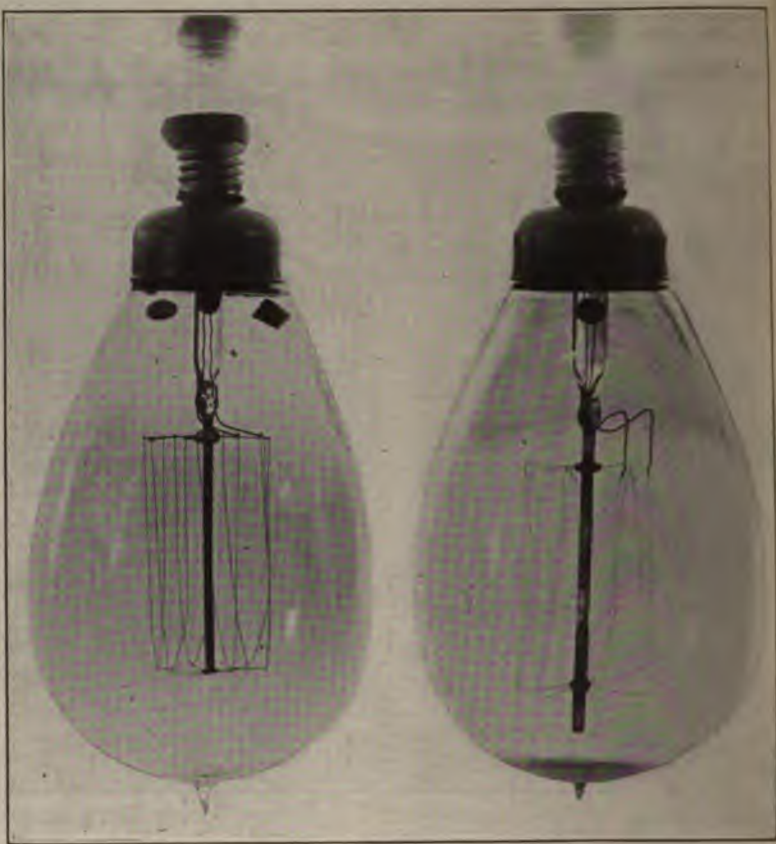


FIG. 3

carefully prepared and placed in the proper position within the bulb, prevented to a very marked extent the forming of the black deposit, and, whatever deposit did occur was light in color, so that the bulb absorption was much reduced.

Later investigations have revealed the fact that there are other chemicals besides those of the halogen group which may

be introduced into the lamp bulb for the purpose of minimizing bulb blackening. The different chemicals are not equally effective in all lamps, for the material used in supports, and the lamp voltage and wattage are factors which may make one chemical more suitable than another for a given lamp. Fig. 2 is a photograph of two 60-watt lamps with and without chemical, which were run to burn-out. The difference is apparent and is seen also in the picture of the 250-watt lamps shown in Fig. 3. The

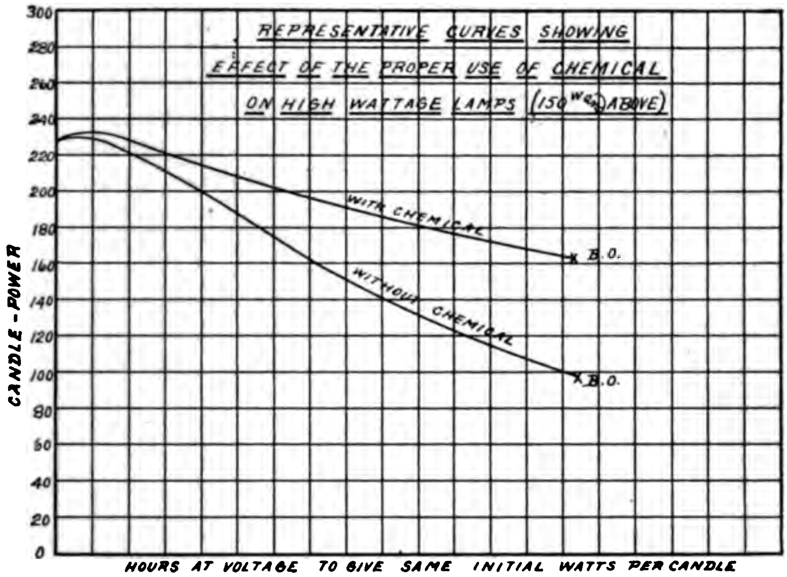


FIG. 4

result is approximately a 15 per cent increase in efficiency of operation for a given number of hours of useful life. The curves of Fig. 4 show the difference in the candle-power performance of a lamp with chemical and of a lamp without chemical, when operated at the voltages which give the same initial efficiency for each lamp. Thus it is seen that by starting the lamp with chemical at a higher efficiency a greater usefulness may be obtained toward the end of the filament life than would be possible without chemical. The result of such a readjustment in efficiency is shown by the curves of Fig. 5.

The use of chemical was not as simple as the inexperienced person might think. Its introduction meant another variable with which to contend and it was not strange that added complications resulted. The processes of manufacture had to be readjusted and much careful experimentation done before its proper use was assured. Each curve of Fig. 6 applies to a single test under a given set of conditions. From these curves it may be seen that the effectiveness of the chemical is a function of the efficiency or operating temperature of the lamp filament when other variables are elim-

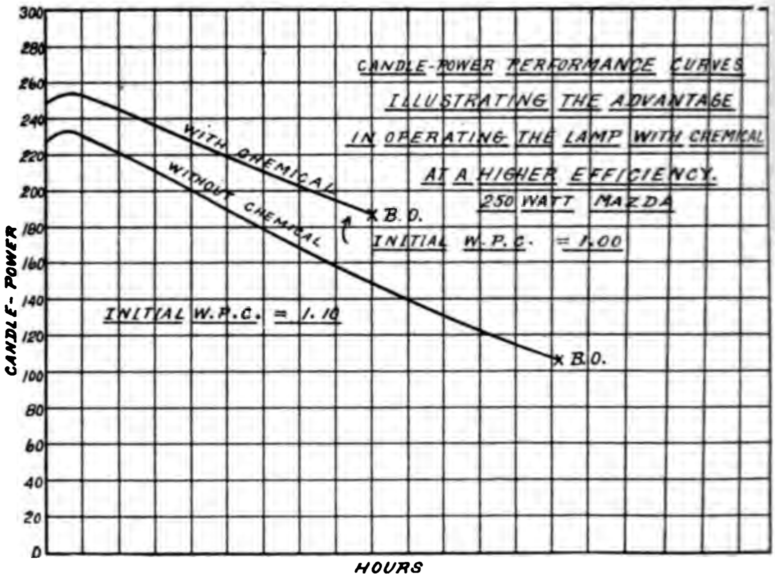


FIG. 5

inated. Great care and accuracy are essential, otherwise the lamp may be no better and may be even poorer. Nevertheless the experience of the manufacturer shows that if the proper chemical is used and proper methods are followed, the results are certain and commercially reliable. Although countless man-hours of the best scientific talent in the world have been devoted to this problem, it can justly be expected that the solution is not yet complete and further improvements along this line may be expected.

Another marked advance which, however, does not show as an increased efficiency, is the increase in the strength of the tungsten wire used as filament material. It is well known that the early tungsten filament lamps were fragile. The progress in strengthening the tungsten filament lamps has much the same characteristic as that shown in the curves of Fig. 1, for progress in efficiency. The increase in strength is shown in Fig. 7. The sudden gain in strength which was made in 1911 was, of course, due to the introduction of the process of making the filaments

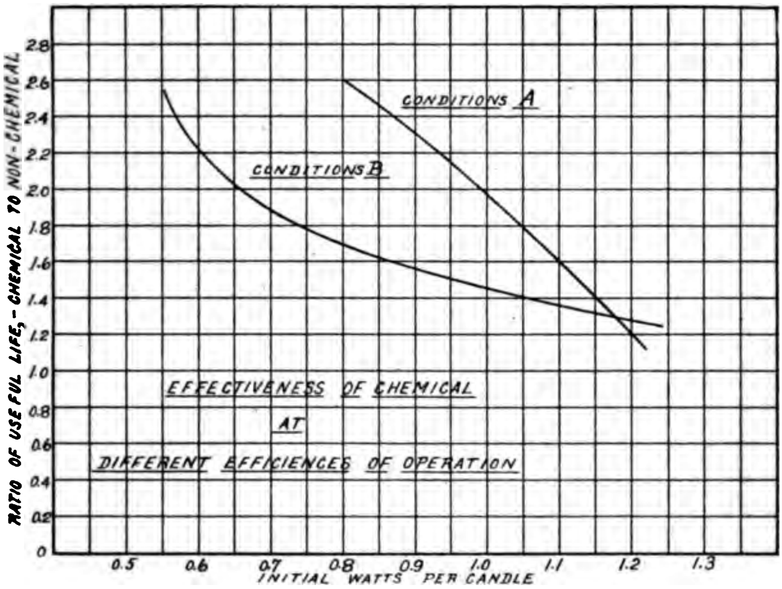


FIG. 6

by drawing into wire which replaced the squirting and cintering process formerly used. The strength and uniformity of the wire have steadily improved as the processes for refining and drawing have been perfected, making possible more rugged and at the same time more uniform lamps.

As the improvements in refining and wire drawing have been made, the manufacturer has become more independent in obtaining his supply of raw material. He can use raw material

to almost any form as regards chemical composition and still produce filaments of uniform quality. Obviously, this feature works to the advantage of the lamp user, in that the uniformity of the product under varying conditions of raw material supply is assured, and also, the shortage of output due to the inability of the lamp manufacturer to obtain a given quality of raw material is eliminated. All the resources of the present-day scientific knowledge of the chemistry of metals have been used in bringing about this condition.

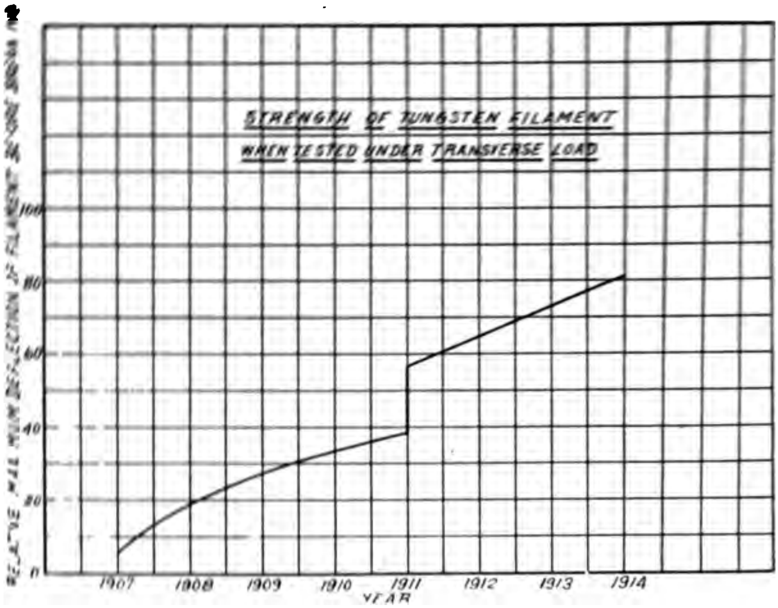


FIG. 7

The more complete standardization of the physical dimensions of the tungsten filament lamps in the regular line furnishes further evidence that the manufacturer is producing more uniform lamps. Fig. 8 is a factory specification sheet for one size of lamp, which indicates something of the efforts that have been made in the standardization of dimensions.

The position of the center of light, with respect to the base contact of the lamps, is at present being maintained within nar-

FILE NO. 95-22M-60

SUBJECT 60W 100-130V S-21-E Mazda

SENT TO X

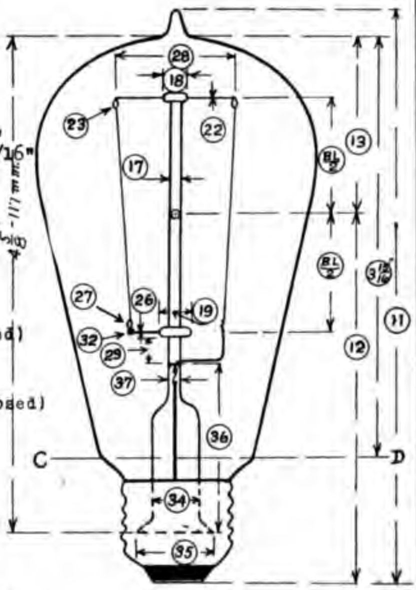
DATE March 26th, 1913.

STANDARDIZING NOTICE NO. SM-60115

SUPERSEDING Sheet dated Jan.22,1913.

BUREAU — M SEC.

1 DATA BOOK SCHED. T-1
2 CLASS Mazda
3 TYPE Straight Side
4 STYLE Large
5 WATTS 60
6 VOLTS 100-130
7 W. P. C. 1.12
8 BULB S-21-El
9 BASE #101
10 REDUCTION FACTOR 78%.
11 MAX. OVERALL LENGTH 140 mm 5½"
12 LT. CENTER (FROM BASE) 87 mm 3-7/16"
13 LT. CENTER (FROM BULB END) 43 mm 1-11/16"
14 DIAM. TOP TUBE 5½ or 6 mm
15 LENGTH TOP TUBE 89 mm 3½"
16 CONTRACTION TOP TUBE
17 BUTTON ROD DIAM. 3 mm (2¾-3¼)
18 MAX. DIAM. TOP BUTTON 5½ mm 14/64"
19 MAX. DIAM. BOTTOM BUTTON 8 mm 20/64"
20 NO. TOP SUPPORTS 6
21 TOP SUPPORT METAL
22 TOP SUPPORT DIAM. 4½ mils
23 TOP SUPPORT HOOK 4½-32-7-3 (closed)
24 NO. BOTTOM SUPPORTS 5
25 BOTTOM SUPPORT METAL
26 BOTTOM SUPPORT DIAM. 13 mils
27 BOTTOM SUPPORT HOOK 13-26-8-3 (closed)
28 MAXIMUM SPREAD 29 mm 72/64"
29 SHANK LENGTH 6 mm (4-8)
30 WINDING No. 1
31 GETTER No. 14
32 GETTER POSITION All bottom hooks
33 GETTER AMOUNT
34 DIAM. STEM TUBING 11 mm (10½-11½)
35 DIAM. FLARE 19 mm ¾"
36 MIN. STEM LENGTH 25 mm 1"
37 THICKNESS STEM SEAL 3½ mm
38 WELD 507-16-4-1656 Copper Tube
39 DIAM. BULB NECK 33.4 mm 1-5/16"
40 PAINT FORMULA No.2
41 EXHAUST SCHED. No. 1 (5-5-2)
42 AGING Sched. No.2
43 STD. PKG. QUAN. 100
44 STD. PKG. WEIGHT 33 lbs.
45 WRAPPER A2145
46 INNER CONTAINER M2195
47 OUTER CONTAINER M21420



L. D. FILE REF. NO 52-22M-60 Sheet No.153

FIG. 8

rower limits than ever before. The average deviation of the light center length from the standard has been reduced to one-quarter of what it was a year ago. Uniformity of light center position is desirable and necessary because of the wide use of reflectors designed for given filament positions. The curves of Fig. 9 show the variation of downward intensity with altered light center length and make clear the advantage of maintaining the proper position of the light source in the reflector.

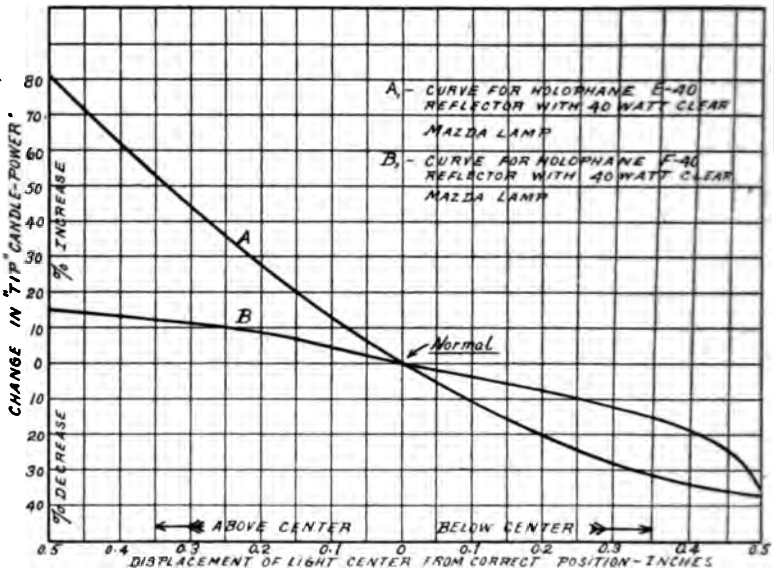


FIG. 9

The manufacturer has been devoting considerable attention to the reduction of the bulb sizes for the low-wattage lamps, including the 100-watt and lower. Fig. 10 shows a photograph of the old 60-watt lamp beside the new small-bulb 60-watt lamp. This is the lamp which replaces the old carbon as regards wattage and bulb size, and gives "three times the light." It is particularly suited to the central-station man's requirements, because his load is not decreased, his storage space for lamps need not be increased, and no change in lighting fixture is called for. The smaller sizes of lamps are used mainly in office, factory and

dential lighting, and it is a distinct advantage to be able to lamps of different wattage in the same fixture without changthe light distribution. A small adapter still permits the of the smaller bulb lamp wherever its larger predecessor used.

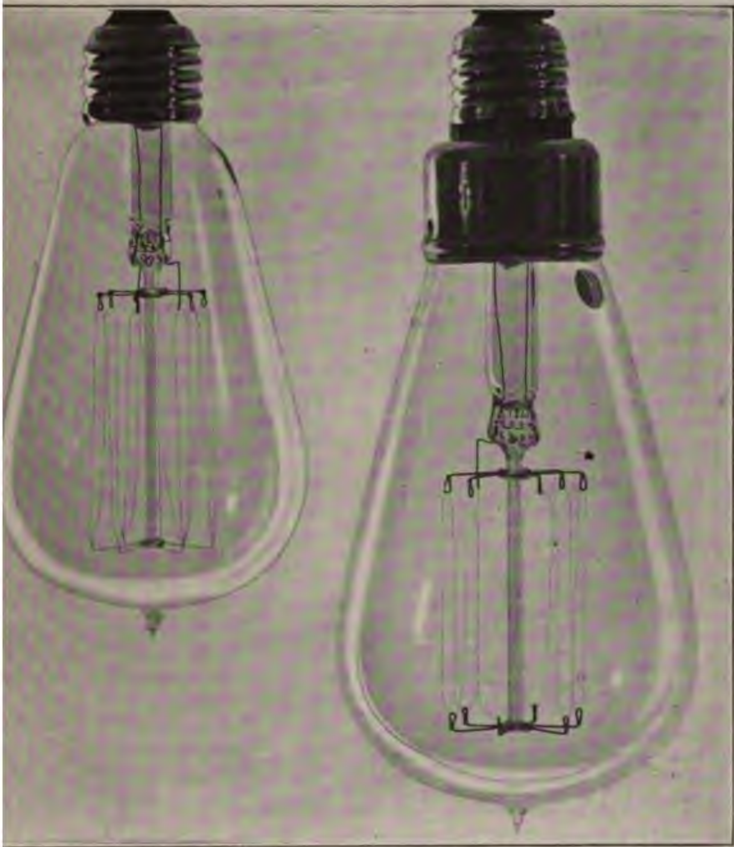


FIG. 10

The introduction of chemical has made possible this decrease ulb sizes which is certain to show up eventually in a reduced :, because less space is required for storage and handling ing the processes of manufacture and later in the warehouse.

Perhaps the greatest development which has taken place recently is that of the so-called concentrated filament or what may properly be called focus type lamp. It has long been recognized that an incandescent lamp with the filament concentrated within a very small volume would fulfil a variety of needs. Wherever it is desirable to project a concentrated beam of light by either of the well-known methods, that is, with a parabolic reflector behind the lamp, or, with a system of lenses before the

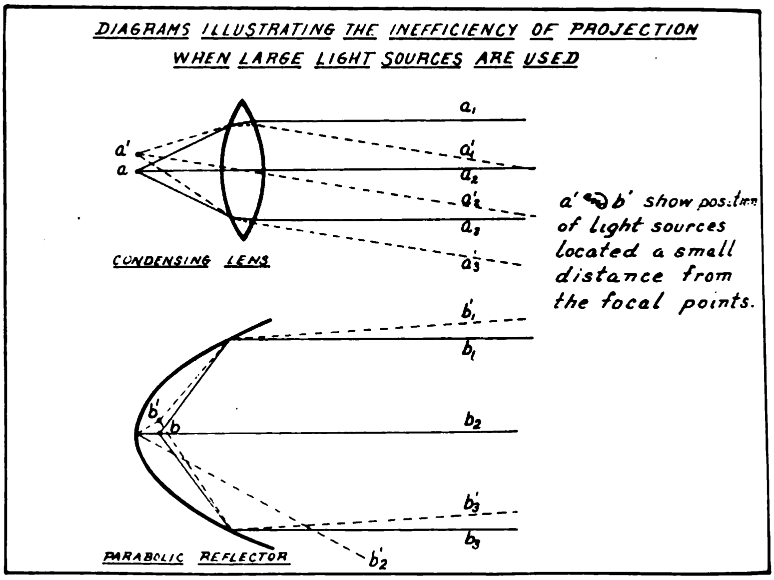


FIG. 11

lamp, it is absolutely essential to have the light source confined within a small space. Fig. 11 clearly shows the necessity of a small source with these devices. Light coming from a point slightly removed from the focus is seen to diverge instead of keeping to the one direction in which it is desired to project the beam. The first accomplishment along this line was the automobile headlight in which the filament was twisted into a small double helix. This lamp proved a phenomenal success from the start, but, at the time of its development, it was not even dreamed that anything but a lamp of very low voltage could be made in

this manner. With these automobile headlight lamps, it was necessary to take care of only a very short length of filament and but three or four turns in the helix were needed. The helices were of relatively large diameter as compared with the diameter of the filament.

The development of the automobile headlight lamp led to experiments with helices of different diameters, and it was soon found that they could be made as small as desired. A small diameter of the helix resulted in the reduction of the volts drop per turn, and therefore, decreased the danger of short-circuit

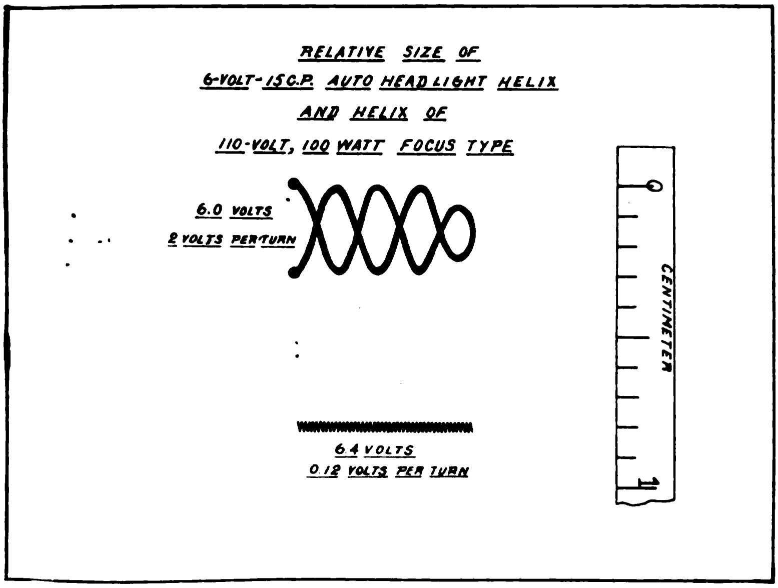


FIG. 12

currents between the coils, so that for a very small helix little or no apparent separation between turns was necessary in order to compel the current to pass around in the wire rather than to jump across between turns. Fig. 12 shows the relative sizes of the helices for the auto headlight and for the 100-watt, 115-volt focus type lamp. It was also found that the wire seemed to be increased in strength by being stressed beyond its elastic limit in the process of winding into the small helix. These fea-

tures pointed to the possibility of taking care of a considerable length of filament within a very small space, and there soon appeared experimental lamps made for 110-volt, and even for 220-volt circuits. Further experiments brought forth a whole line of standard focus type lamps of proven ability to fulfil the requirements of the service. Fig. 13 is an illustration of the 100-watt size. It is representative of all available sizes as regards construction.

FIG. 13

It is possible to take care of even greater length of filament in a given space by making what may be called a double helix. The wire is first wound into a regular small helix and this small helical winding is, in turn, used in making another helix of larger diameter. Fig. 14 shows the appearance of a section of this double helix.

Many interesting problems were encountered in the production of these lamps. It was found that the manufacturing data

the regular product did not apply to the wire when wound
o these small helices. A single experiment is made to show
e point of difference. Take a piece of wire and wind part of

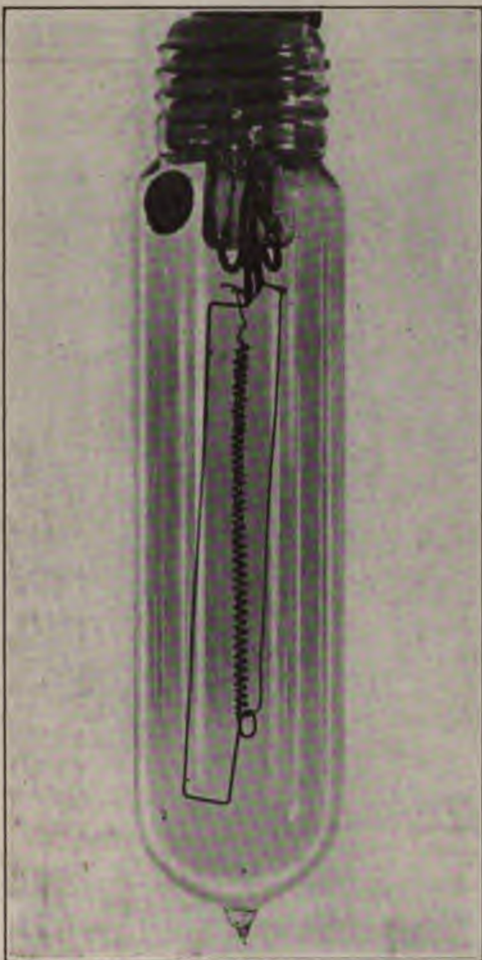
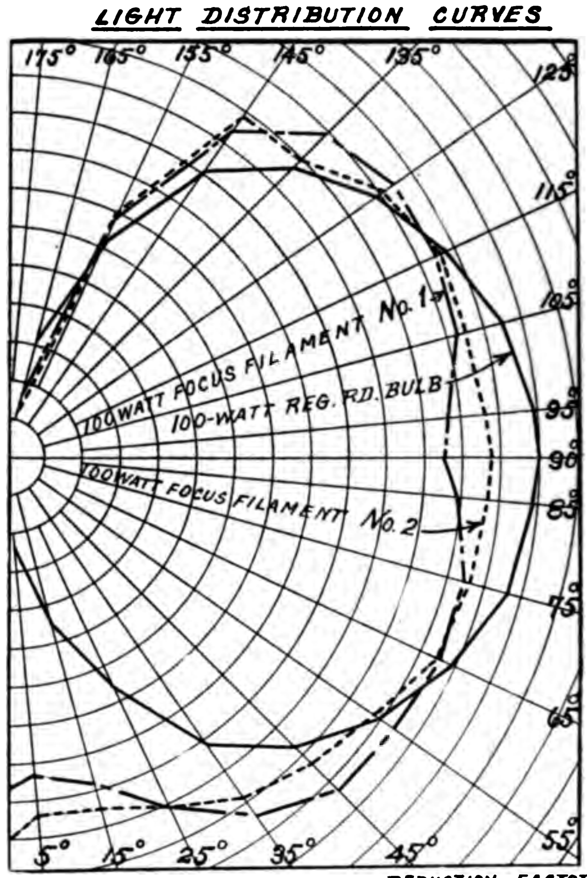


FIG. 14

nto a small helix and allow the other part to remain straight
in the regular lamps. It is noted when increasing the cur-
t through a lamp made with this dual filament construction

that the coiled part begins to glow first. The brightness of t
glow is a measure of the relative temperature, so that in ord
to produce a lamp which will operate at a given current a
temperature, it is necessary to use larger wire in the focus ty



		REDUCTION FACTOR
100-WATT	REGULAR RD. BULB	81
100-WATT	FOCUS FILAMENT No. 1	98
100-WATT	FOCUS FILAMENT No. 2	89

FIG. 15

The rating of these lamps cannot be done in the ma
employed for regular lamps, in which the horizontal ca
power bears a nearly constant ratio to the total light emi

and therefore can be taken as a measure of the total light. With the focus type no such degree of uniformity of this ratio prevails, so accurate rating becomes the prolonged process of obtaining the voltage which will result in a certain desired watts per unit of total light emitted; and a subsequent measurement of the watts per mean horizontal candle-power will be no accurate

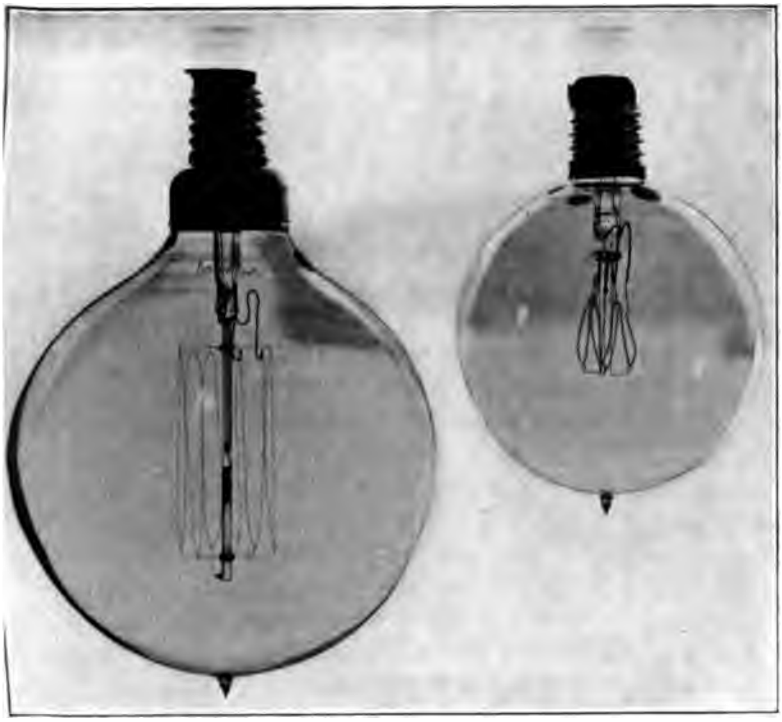


FIG. 16

measure of the actual efficiency of operation. Fig. 15 shows light distribution curves for regular 100-watt round bulb lamps and for two focus type lamps giving the same total lumens as the regular one. The chief difference in the curves for the focus type is found in the variation of the horizontal candle-power. The most careful inspection would not enable one to predict that these differences would occur.

It will be noted that the bulb sizes on the focus type a smaller than for the regular line. Chemical is used in these lamps and, in a measure, counteracts the effect of the small bulb. Although the considerable reduction in bulb size means a sacrifice in performance, yet such a reduction in bulb size is especially desirable in the case of the focus type lamp. The efficiency of the utilization of light from focus type lamps depends upon the nearness of the source to the parabolic reflector or lens, as the case may be, and, since it is desirable to place the filament in the center of the bulb, the focus type limits the focal length of such devices to one-half the bulb diameter. According to the practise employed in the building of regular mazda lamps, 500 watts calls for a bulb of 8 in. in diameter. The 500-watt focus type lamp is built with a 6-in. bulb for the reasons given above. Fig. 16 shows 500-watt lamps of both the regular and the focus type.

Since a very high efficiency of operation is called for, these lamps cannot be made for as great a life as the regular line. For the purposes for which they are used, high efficiency is far more essential than long life.

Earlier in this paper it was mentioned that focus type lamps would fill a great variety of needs. It will be of interest to note some uses which constitute the field of this new type of lamp. The 100-watt focus type lamp will operate small stereopticons very successfully, being especially suitable for small lecture rooms and for residences. It can also be used with certain devices for projecting advertising matter on sidewalks and walls. Focus type lamps are found very useful by physicians and dentists for projecting an intense spot of light to a point where they are working. When used with parabolic reflectors, they find a considerable field in producing special effects in the lighting of architectural designs from distant and concealed places. According to present plans, this will be especially exemplified by much of the lighting done at the Panama-Pacific Exposition.

The focus type lamp has made possible the powerful headlights used on electric vehicles and electric railway cars. They can be used with success in searchlights, although they are not tly powerful to take the place of the high-powered arcs. ected that the focus type will find a wide field of usefulhting the stages of theaters. In fact, wherever it is

necessary or desirable to produce a highly concentrated beam of light, this new lamp can well be considered as a means for producing it.

The focus type, of course, possesses many advantages over the arc for purposes of projection, in that it is perfectly steady, and requires no rheostat and no attention other than switching on and off. Wherever it is at all possible to produce the desired results with the incandescent lamp, it will, no doubt, be used in preference to an arc lamp.

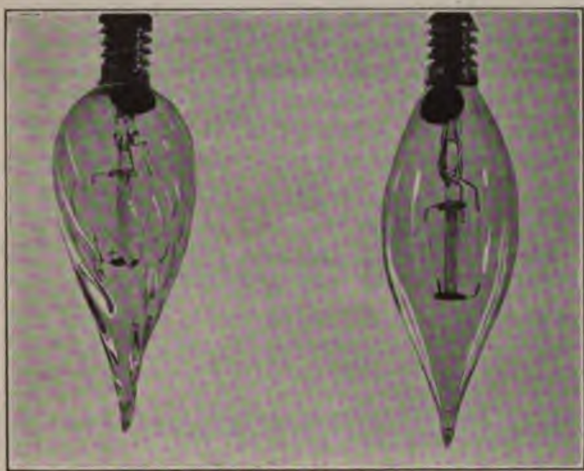


Fig. 17

Two new lines of lamps have been made possible by the introduction of the helical filament, namely the 100 to 130-volt candelabra line and the new 100 to 130-volt show-case line. The helical filament is especially well adapted for the high-voltage miniature style or candelabra type of lamp in which a small amount is necessary. Fig. 17 shows 15-watt lamps of this type. The long tubular lamp shown in Fig. 18 meets a much felt demand in showcase lighting. The individual lamps operate directly on the voltage of the lighting circuit and require no series connection. The helical filament extends the entire length of the bulb and is supported by an iron wire which

serves to carry the current to the far end of the filament as well as to hold the intermediate supporting hooks.

It may justly be expected that the focus type lamp will find even other fields of usefulness than those outlined above.

The foregoing may be considered as a report from a lamp manufacturer to the users of incandescent lamps on the recent developments of the product. However, these developments are not due to the efforts of a single laboratory, but to the combined

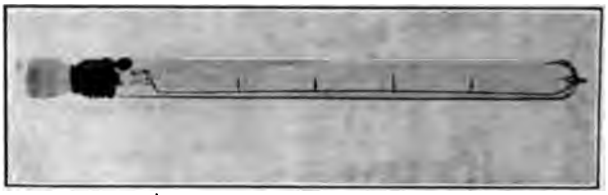


Fig. 18

efforts of the various research laboratories, and that "team work" which is so essential to the most rapid progress in the development of any art. It is seen that marked improvements have been made in the regular line and that important new developments have taken place within the past year.

The Chairman: I will now ask Mr. Howell to come up on the platform and start the discussion on these papers.

DISCUSSION

Mr. John W. Howell, Harrison, N. J.: Gentlemen, your Lamp Committee performs two functions. It reports to you through the Committee the progress made in the development of the electric lamp, which is very useful to you. It also acts as a spur to the manufacturers to give the committee something to report, which is also beneficial to you.

A year ago at this meeting your Lamp Committee reported on the improved quality of high candle-power lamps. To-day they have added to the list of lamps improved the 60-watt and the 100-watt lamp. The 60-watt lamp and the 100-watt lamp are to-day twice as good as they were a year ago. Your Com-

mittee does not tell you they are, but they are twice as good as they were a year ago. That means, that their life, with the same efficiency, is twice as long to-day as it was a year ago. The chemical introduced into these lamps, which is referred to by Mr. Randall, we call "a vacuum getter." That is a rather homely name, but it sounds better than "the chemical." The vacuum getters are being applied to all our lamps as fast as we can learn how to do it. The application came first to the lamps with a thick filament, as they were easiest. It is easier to obtain the desired action in a thick filament lamp than it is in a thin filament lamp. Even now we do not know how to apply these chemicals to our thin filament lamps, but we are progressing. During the year we have added the 60-watt, and we shall go further during the next year.

Vacuum getters have been introduced in other lamps which your Committee has not reported upon. Railway lamps during the last year have been treated with it, and they are to-day twice as good as they were a year ago. Train lighting lamps and also the larger types of series street lamps have been treated the same way, and they also are twice as good as they were a year ago. The automobile headlight is now included in the list. Those lamps are hardly on the market as yet, but all lamps made to-day are so treated, and their quality is very much better than it has been in the past.

Your Committee reports on the 10-watt standard voltage lamp. That lamp to-day is five times as good as it was a year ago. That improvement, however, is not due to chemical means. It is due simply to our having learned how to make them properly, and to prevent the overlapping of the filaments, which had been one of the chief difficulties.

The report of your Committee states that not only has the quality of all these lamps improved during the year, but the price has tended continuously downward. So it has, and it is our duty, the duty of the manufacturers, to see that those tendencies continue; that the quality continues to improve, and that the price continues to come down; and as the price comes down and the quality goes up, the value of the lamp per dollar is so much greater that, as your Committee reports, the mazda lamp is rapidly superseding the carbon and gem lamps.

If anyone sits down and figures the relative values of the gem lamp and the mazda lamp, considering their present quality

and prices, he will convince himself that the mazda lamp is a more economical lamp for him to use than the carbon or gem. So I prophesy that within a very short time there will be only one lamp on the market, and that the mazda lamp.

Your Committee refers to the gain in street series lamps, due to improvement in the accuracy of making wire, so that lamps can be made to the absolutely correct amperage. That has all been done during the present year, so that whereas previously we sold lamps of 6.4 to 6.8 amperes, we now make them all 6.6 amperes, and customers are adapting their appliances to the use of the one standard amperage of 6.6 only, and that is a simplification in the business. It simplifies the stock we have to carry, it cheapens the lamp, we do not have to make so many varieties, and anything that cheapens the lamp reduces the cost, as you can see, in constantly progressive reduction.

The same improvement in accuracy which has been noted in the series, sign and railway lamps, applies to all multiple lamps, in fact to all lamps, so much so that lamps now are made very accurately to voltage. As you all know, in making carbon and gem lamps it has been impossible to make them to voltage. If we attempted to make a 110-volt lamp we would make it all the way from 105 or lower to 115 or higher. Although they were designed to be 110, they are not 110, and they have to be measured, marked and sold accordingly. That condition no longer exists in mazda lamps. Lamps made for any voltage measure that voltage as accurately as we can measure it.

The great range of voltages which are used by central stations for incandescent lamps—as you know, the voltage ranges from 104, or lower, to 122, or more—is due to the fact that in carbon and gem lamps we could not manufacture the voltage. As our stock of lamps accumulated in voltages for which we had no orders, new plants using large numbers of lamps would be placed at that voltage, so as to use up lamps which we necessarily made in our effort to make others. In general that condition still exists for carbon and gem lamps exactly the same as it did before. Neither of them can be made exactly to voltage, to diameter, or to resistance, and as long as those lamps are used, this condition will exist; but with the mazda lamp it does not exist. If we had started with the mazda lamp in the condition in which it is to-day, we would have made our lamps to one voltage only and

all your plants would have been at one voltage—a very desirable state. We hope some day to bring that about, to make all operating stations run at one voltage. When that time comes—and, of course, it will be when carbon and gem lamps have passed—there will be a very considerable reduction in the cost of manufacturing lamps and in the cost of manuufacturing apparatus. It will reduce the cost of lamps, the cost of generators, and, ultimately, the cost of electric lighting.

Now, Mr. Randall has told you of the improvements of the past year, and that they were made in the laboratories of the General Electric Co. You may like to get a little knowledge of the extent of that work in the three or four laboratories of the company. There are over 50 first-class scientific research men working on lamps alone. These men have over 60 assistants who are also skilled men, and most of them college graduates, besides a very large number of helpers and subordinates. These men are all working to improve the quality of the lamp, and, incidentally, to give your Lamp Committee something to report on next year. We intend to keep it up and expect to make the lamps better. There are two lines of work going. Many men are working to make the lamps better, some are working to make them cheaper. When you make a lamp better you usually make it cheaper—not always, but usually. It is a remarkable thing that when you do improve a lamp you make it cheaper. That tendency will, no doubt, continue, and when I come before you again, I shall tell you more that we have done during the current year.

Mr. Norman Macbeth, New York City: One point that I would like to bring up in connection with this report of the Lamp Committee in reference to the tables showing the percentage of carbon, gem, tantalum and mazda lamps is that it seems to me if this table had been based on the light production possibilities of the lamps rather than on numbers of lamps the results would have been more favorable. While there are not as many large mazda lamps used as of the smaller sizes, the method of calculation adopted by the Committee would result in one 8-c-p. carbon filament lamp offsetting a 400-c-p. mazda lamp, and in the case of a 100-watt mazda lamp used to substitute a 5-16-c-p. lamp cluster, the committee report would recognize this as five carbon lamps against one mazda lamp, whereas on the light output basis it would be an almost equal exchange.

The result of a table giving the percentages as above but based on light output rather than on number of lamps, would undoubtedly raise the percentage of mazda lamps from approximately 40 to 60 or perhaps 70 per cent. As a matter of fact a large number of the carbon lamps at present in use are in locations where short hours of burning are the rule, and it is probable, considering the quantity of light produced with incandescent electric lamps in this country, that 80 per cent of the lighting hours are taken care of with mazda lamps. I believe that this change of rating would have an effect worth while on consumers and central stations likely to be influenced by the action of the majority and who would hesitate to change their carbon-filament lamps on the statement that 40 per cent only of the lamps used during the year 1912 were mazda lamps.

THE CHAIRMAN: Mr. Willcox has come in. As we have not seen anything of him for a couple of years since he went to London, probably he would like to say a word on the lamp situation.

MR. F. W. WILLCOX, London, England: Mr. Chairman, this is totally unexpected. I do not feel that I can add anything to the very interesting discussion. I came to learn, and I have already learned more than I can contribute.

The work that is going on in the States in connection with lamp development appeals to me, particularly after my two years' absence, as most remarkable. Especially when judged by European standards the pace is tremendous. I only wish it were possible to extend to England, where the electrical density is only a fraction of what it is in the States, some of the development work and aggressive co-operative effort which is so productive of results here.

I have just been making a few figures to show you the difference. The consumption here to-day in the States, as you see, aggregates about ninety million lamps a year with a population of about ninety million, or about one lamp per capita. In Great Britain, with a population of about forty-five million, it runs only about twenty million lamps per year, or half a lamp per capita. Furthermore, the electrical growth in this country, which, as you see, is from five to ten million lamps per year, is a very large fraction of the total consumption of lamps in Great Britain. Conditions, therefore, are quite different in these two countries, and I only wish for the growth of the business

over there that they could catch some of your speed in electrical development.

The particular things we are interested in in Great Britain are, of course, the production and development of the higher voltage lamps, and the problem there is a little different from what it is here, as over 65 per cent of the electrical installations are 250-volt installations, while here the proportion of 250-volt installations is very small. In general, the tendency abroad in connection with lamp usage, and the replacement of other forms of lamps with incandescent, tungsten lamps, is very similar to what it is here. They follow the same general practise of utilizing the very high efficiency of the tungsten lamp in substitution for the arc lamp and all other forms of lamps, and the stimulus that the tungsten lamp is giving has resulted in greater extension acceleration than heretofore known.

These are epoch making statements that we have heard today from Mr. Howell. This wonderful development of the tungsten lamp has brought with it gains of accuracy in actual lamp production, so that the possibility of having one voltage only is now within sight, and the assurance of still further reductions in cost, a lamp which will be continually cheaper, and may possibly compare with the carbon lamp in ultimate cost. These conditions seem to me to lead to one general result, the universal substitution of the tungsten lamp for all other forms of electrical illuminant.

It was a fortunate thing for the industry that an electrical development of this kind came in the form of the simple incandescent lamp. It might not have done so. It might have come in like the Nernst lamp, or a lamp having movable parts, but instead we have it in the same simple form we have always known, with all the advantages that gives us. That is a great heritage and a fortunate thing for the electrical industry.

THE CHAIRMAN: Are there any comments to be made, gentlemen, on this report? If not, we will proceed with the reading of the paper "The Relation of the Incandescent Lamp to Lighting Service," by Mr. M. D. Cooper and Mr. R. E. Campbell, of Cleveland.

MR. M. D. COOPER, Cleveland, Ohio: In opening this subject the authors wish to acknowledge their indebtedness to the Cleveland Electric Illuminating Co. for their very kind cooperation.

THE RELATION OF THE INCANDESCENT LAMP TO LIGHTING SERVICE

In the early development of a central station the securing of more customers and more revenue are most important items, and although the quality of the service is necessarily kept in mind it is still subservient to the pressing need of extension and growth. As time elapses the item of service grows in importance as compared with the item of revenue until the present day conditions are reached, when the two are recognized to be of about equal importance. Much has been written on the subject of the service rendered by central stations to their customers. A great deal has been accomplished toward the end sought—that of complete, satisfactory and economical electric service. In view of the short time which the industry has had to reach its present state of development, it follows that we can logically expect continued activity tending toward further improvement, extension and economy of service.

It is interesting to note in this connection, that although the cost of living has increased, the cost of electricity has decreased. Changes in the rates of charge for electric service are almost entirely in the downward direction. Even though the actual charges for electrical service had remained unchanged, the cost would be less than formerly, for the reason that many additional items of benefit to the customers are now included in the term "central-station service."

The authors wish to discuss a subject which is vital to good service and which apparently has not as yet received the attention it merits. This subject pertains to the voltage drop between the customer's service and his load. Central stations annually expend large sums of money to maintain a uniform and constant voltage at the services of all their customers. The manufacturers of current-consuming devices likewise put forth every effort to make their products adhere closely to the voltage rating. This honest endeavor has had and will continue to have its results in the increased use of electricity. The benefits of this endeavor may be even more fully realized if greater attention is given to the question of interior voltage drop.

Although the central station cannot be held either morally or legally responsible for the conveyance of electricity from the

service switch to the current-consuming devices, this subject merits attention because it affects both revenue and the quality of the service rendered to the customers. If service to a customer should be greatly impaired by a particularly bad example of interior drop, in the customer's mind the central station would have to bear the burden of the criticism.

The entire elimination of interior voltage drop is a physical impossibility. It may be decreased but never abolished. Therefore, the remedy must be a compromise between elimination of the cause and adaptation to the effects.

LIGHTING SERVICE AS AFFECTED BY VOLTAGE DROP

The term "lighting service" may be used to designate the degree of satisfaction which a customer derives from the use of electricity as a means of producing light. Due to the high efficiency of modern electric lighting the use of other illuminants is rapidly becoming less widespread than was the case a few years ago. The safety, convenience, adaptability and economy of such illuminants as the tungsten-filament lamp, for instance, have given a strong impetus to this branch of central-station service.

In electric lighting and particularly in incandescent lighting, as in no other one branch of the electric supply industry, satisfactory operation depends upon a very close co-ordination of the voltage of supply and the rated voltage of the translating devices.

The larger central stations maintain so-called "flying squadrons" who make periodic tests of the line voltage at the service switch on the premises of their customers. This enables the station to maintain a fairly uniform voltage at the point where the service enters the premises of its customers, but it takes no account of the voltage drop between the service switch and the lamp sockets.

An incandescent lamp fulfills its rated performance with respect to wattage, candle-power, and life only when burned exactly at its rated voltage. If the voltage supplied is less than the lamp voltage, its wattage consumption is decreased in a certain proportion and the candle-power in a much greater proportion, thus decreasing the efficiency of light production. If the voltage supplied is greater than the lamp voltage, the wattage, the candle-power and the efficiency are increased, but the life of

the lamp may be unduly shortened. The total cost of light consists of two elements; the cost of energy and the cost of renewals. Since the economy of light production depends upon a proper balance between these two components of the total cost, it is highly important that the balance be preserved by operating the lamps under the voltage conditions which are universally agreed to be the most suitable for yielding simultaneously the proper quantity and a good quality of light, the proper revenue to the central station and the proper economy of light production.

As far as the quality of lighting service and the revenue obtained therefrom are concerned, if undervoltage burning exists, it makes no difference whether it is caused by the selection of an improper lamp or by lack of detailed knowledge of the exact voltage conditions existing on the system—the result is the same, less light, poorer quality of light, less revenue to the central station, dissatisfied customers and an opening for competing illuminants.

OPERATION OF ACCESSORIES AS AFFECTED BY VOLTAGE DROP

The effect of a considerable drop in voltage on the operation of the various auxiliary electrical appliances is somewhat similar to the effect on an incandescent electric lamp. In other words, the manufacturers of these appliances have established definite voltage ranges within which their operation will give satisfaction. The impression has existed that incandescent lamps require much closer voltage regulation than any other class of load, but it is found that various electrical appliances (other than those motor driven) require nearly as close voltage selection and voltage regulation as is necessary for the successful operation of lamps. Appliances of the heater class, such as flat-irons, curling-iron heaters, warming-pads, etc., are rated by their manufacturers in steps of from 5 to 10 volts, showing that the voltage limits for satisfactory operation are from 2½ to 5 volts either side of the rating. Appliances of the cooking class, such as toasters, percolators, grid-irons, broilers, etc., which demand somewhat closer temperature regulation, are rated in smaller steps of from 3 to 7 volts, showing that the voltage limits for satisfactory operation are from 1½ to 3½ volts either side of the rating. If the voltage supplied to the apparatus is lower than that at which it was intended to operate, the time required for producing the heat

necessary for economical and successful accomplishment of the work in hand is too great. The result is, in many cases, a return to the earlier heating methods in use before electricity became economically and satisfactorily available. These close voltage limits in the ratings of appliances have been adopted by manufacturers because they recognize that the economical and satisfactory operation of a majority of these appliances depends upon the time required to attain a certain heat and this in turn upon the voltage at which current is supplied. The importance of proper selection of apparatus with regard to the voltage at the point of attachment will therefore be fully appreciated.

OBJECT OF INVESTIGATION

In previous work on voltage conditions as found on the circuits of central stations, the authors found numerous cases where lighting service had been seriously impaired by interior drop. Some of the particular instances were so flagrant, and the resultant dissatisfaction with electric service was so great, that it seemed an investigation of the subject of interior voltage drop might bring forth facts which would be of general benefit. The object, then, of this investigation of voltage drop between the service switch and the lamp sockets was to obtain, if possible, some information which would show an approximately average drop for various classes of lighting; to show, further, in some measure, the importance of taking this factor into consideration in the selection of lamps and appliances for use on central-station circuits.

METHOD OF INVESTIGATION

In securing locations for tests no attempt was made to select buildings which to the previous knowledge of the authors might show abnormal conditions. The only criterion in the selection was the consent of the occupants of the building. It was attempted to include in the investigation such buildings as would be typical of the main classes of central-station load, such as industrial, commercial and residential installations. In order to eliminate from the data the effect of slight fluctuations of line pressure it was necessary to take simultaneous voltage readings at the service switch and at the lamp socket. This was accomplished by the use of stop watches. Readings of the service voltage were taken

every half minute, and all readings at lamp sockets were taken at times corresponding. The voltmeters used were very carefully calibrated, and any difference in their indications has been eliminated from the data.

Since practically all of the voltage measurements were taken during daylight hours, it was necessary to turn on the lamps during the test. An effort was made to avoid loading the circuits beyond the point which would be representative of the installation. In the case of residences the tests indicate load conditions somewhat heavier in comparison with the maximum demand than in the case of commercial and industrial installations. This is due to the fact that in residences the tests were made on the house as a whole, while in industrial and commercial installations practically separate tests were made on each floor or subdivision of the building. In the case of residential tests, the data on drop due to lighting load were supplemented by data on the drop caused by the addition of various appliances, such as flat-irons, toasters, heating pads, percolators, etc.

Tables I, II and III show the results of the investigation of interior voltage drop. Under the heading "Maximum Volts Drop" is shown the maximum difference between socket voltage and service voltage which was encountered in the tests at each place. The "Average Volts Drop" is the average of all such differences. The total lighting load is the total load which was turned on during the time the readings were taken. It does not represent the total connected load. In residential service and particularly in apartments the number of risers from the services to the secondary distributing panels may be very small, hence it might be expected that the average drop would bear some relation to the total load. For this reason the average drop is divided by the kilowatt load and listed as "Average Drop per Kilowatt" in the table on residential service.

DATA SECURED

TABLE I

Industrial Service

No.	Description of Product	Max. Volts Drop	Ave. Volts Drop	Total Lighting Load-kw.	3 wire or 2 wire	
1	Brass specialties	9.4	4.1	5.3	3	
2	Lamp factory	3.2	1.9	3.0	3	
3	Boiler and plate shop	5.5	3.1	11.2	2	220 volts only
4	Machine shop	3.8	2.1	6.1	2	
5	Foundry	4.5	2.5	4.2	3	
6	Varnish factory	2.0	1.7	2.2	3	
7	Clothing factory	4.4	2.4	6.0	3	
8	Heavy castings	9.2	3.4	4.8	2	
9	Plate and structural iron	9.4	4.6	10.5	2	
10	Brewery	6.5	4.5	4.7	2	
11	Machine shop	3.8	3.1	3.1	2	
12	Machine shop	4.3	3.2	9.1	3	
13	Stove factory	6.2	4.2	8.3	2	
14	Box factory	3.2	3.0	2.7	2	
15	Knit goods factory	3.3	2.2	4.2	3	
16	Fixture factory	3.6	2.1	4.4	3	
17	Machine shop	3.2	2.0	3.9	2	
18	Machine shop	3.7	2.4	5.2	3	
19	Carding mill	8.1	4.7	5.3	2	
20	Art glass	3.5	2.1	1.2	3	
21	Awnings	4.7	3.4	2.2	3	
	Average	5.02	2.94	5.1		

TABLE II

Commercial Service

No.	Description	Max. Volts Drop	Ave. Volts Drop	Total Lighting Load-kw.	3 wire or 2 wire
1	Wholesale hardware	4.7	2.8	4.0	3
2	Hotel	4.9	2.9	1.0	3
3	Hotel	4.6	3.1	48.0	3
4	Restaurant	5.2	3.9	3.0	3
5	Wholesale hardware	*14.2	11.3	4.3	3
6	Cigars and billiards	3.8	2.7	1.2	3
7	Wholesale hat	3.0	3.3	0.6	3
8	Office supplies	5.3	2.5	12.3	3
9	Office building	5.9	4.3	60.0	2
10	Restaurant	2.2	2.0	0.5	2
11	Restaurant	2.5	2.2	1.0	2
12	Club building	2.9	2.0	3.2	3
13	Small office building	3.1	2.8	3.1	3
14	Retail furniture	6.8	4.4	13.4	2
15	Small theatre	7.2	2.2	3.4	3
16	Storage	2.1	1.1	2.7	3
17	Storage	2.9	2.0	4.4	3
18	Department store	3.9	2.2	7.7	3
19	Small office building	2.1	1.4	1.4	3
20	Wholesale liquor	3.4	2.9	1.3	3
21	Retail glass and paint	2.4	0.9	1.4	3
22	Garage	*21.0	20.0	2.7	2
	Average	3.94	3.03	10.9	

* Excluded from average, since these are evidently isolated cases of abnormal conditions.

TABLE III

Residential Service

Apartments

No.	Floor	Lighting Load Watts Load	Volts Drop Max.	Volts Drop Ave.	Volts Drop Ave. per kw.	Increment due to Acce[ss…] Watts Load	Volts Drop	Vo[lts] Dr[op] per [kw.]
1	2	475	2.2	1.3	2.7			
2	1	1,000	2.7	2.0	2.0			
3	3	400	4.2	3.5	8.8	900	6.5	7.
4	3	400	1.4	1.2	3.0			
5	4	300	4.4	3.7	12.3	900	7.8	7.
6	1	420	1.4	0.9	2.1			
7	1	260	1.2	0.9	3.5			
8	2	350	1.8	1.4	4.0			
9	2	300	1.7	1.5	5.0			
10	1	475	2.4	2.2	4.6			
11	2	375	1.7	1.3	3.5			
12	1	735	3.2	2.4	3.3			
13	2	600	2.9	2.2	3.7			
14	2	425	2.1	1.8	4.2			
15	3	750	2.5	1.7	2.3	500	2.1	4.2
16	2	520	1.8	1.7	3.3	1,000	7.5	7.5
17	2	260	0.8	0.6	2.2			
18	1	280	2.3	2.1	7.5	500	2.5	5.0
Average		462	2.26	1.80	4.33	798	5.28	6.36

Houses

No.	Floor	Watts Load	Max.	Ave.	Ave. per kw.	Watts Load	Volts Drop	Volts Drop per kw.
1		435	2.0	1.1	2.5	560	2.0	3.6
2		600	1.6	0.6	1.0			
3		1,485	2.3	1.6	1.1	440	3.3	7.5
4		440	1.7	1.3	3.0			
5		400	1.2	1.0	2.5	1,250	3.1	2.5
6		525	1.2	0.9	1.7			
7		640	1.0	0.8	1.2			
8		475	2.0	1.7	3.6			
9		960	1.5	0.7	0.7			
10		345	1.3	0.9	2.6			
11		860	0.9	0.6	0.7			
12		685	3.4	2.7	3.9			
13		500	1.5	1.0	2.0			
14		825	4.3	3.1	3.8			
Average		655	1.85	1.29	2.16	750	2.80	4.52
Average for residential service		547	2.08	1.57	3.38	767	4.35	5.6[illegible]

In order to know what amount of voltage drop occurs mo[st] frequently in each of the three classes of load, the following ta[ble] is given, which lists the results according to the amount of av[er]age voltage drop found in each building tested.

TABLE IV

Average Drop Volts	Industrial No.	Industrial Per cent	Commercial No.	Commercial Per cent	Residential No.	Residential Per cent
Under 1	0	0	1	5	9	28
1.0 to 1.9	2	9	2	10	14	44
2.0 to 2.9	9	43	13	65	6	19
3.0 to 3.9	5	24	2	10	3	9
4.0 to 4.9	5	24	2	10	0	0
Total	21	100	20	100	32	100

TABLE V

SUMMARY

Service	Average Load Kw.	Volts Drop Max.	Volts Drop Ave.	Gain by eliminating effect of voltage drop: Per cent Gain to customer in Candle-power	Gain by eliminating effect of voltage drop: Per cent Gain to Central Station in Current Sales
Industrial	5.1	5.02	2.94	10.4	4.4
Commercial	10.9	3.94	3.03	10.8	4.6
Residential	0.55	2.08	1.57	5.4	2.3
Grand average ...		3.68	2.5	8.9	3.8

The grand average of this table is obtained from the average for the three different classes of load by attaching equal weight to each class. As applied to the load conditions of any particular station, the true general average might be either higher or lower, depending upon the relative importance of the three classes of load. The tests represented by the above summary were all taken in Cleveland. Taking all conditions into consideration it is believed that the class of wiring done in this city is representative of that which would be found in other cities.

It is therefore evident that a figure of at least 2 volts for the average interior drop indicates in a conservative manner the conditions which may be found throughout the country.

Examples

It might be interesting to note the extremes of conditions which were encountered in various tests. In one large residence which had nearly a kilowatt of lighting demand, the average of seven readings taken at various places about the house showed an average drop of only 0.7 volt. This was the only residence encountered which had separate and special provision for the conveyance of current to electrical appliances. In contrast to this may be mentioned the case of a large residence not in Cleveland, however, in which a drop of 20 volts was found. (See Table

11). The no-load voltage was 105 volts (using 110-volt lamps); with an 1800-watt load the voltage dropped to 85 volts.

Another illustration of the effect of poor wiring is given in an article by Mr. C. E. Van Bergen, Secretary and General Manager of the Duluth Edison Co., Duluth, Minn., in the "Central Station" for July, 1911, part of which is quoted as follows:

"One of our customers made complaint the past winter of poor light, together with the statement that the more lamps turned on, the less illumination was secured. Upon investigation it was found that one circuit had only bell-wire in it carrying six lamps, and as stated one lamp gave fair light, while with six turned on the filaments were scarcely more than red. This house was wired over twenty years ago."

He also stated, "central stations must keep the matter of illumination before architects, the tendency being ever to cut and economize on this portion of building expense. An instance of this false economy came recently to our attention when we were asked to make an estimate on the expense of installing a heating circuit in a large residence only two years old. No provision had been made for baseboard outlets for the stand lamp in the reading room, and this lamp having been attached to the wall bracket, the bracket became loosened and presented anything but a pleasing appearance. Each new house should have provision made for a heating circuit on which may be used a luminous radiator, an electric iron or a vacuum cleaner."

The customer's opinion of central-station service, as influenced by the matter of interior drop, may be illustrated by the case of a large garage, not in Cleveland, however. In this place the service had been changed from an isolated plant to that of the central station. At the time of this change the properietor replaced a number of 60 watt carbon lamps with 250-watt tungsten filament lamps. The readings taken throughout this building showed that under the increased load condition the average drop was 20 volts, with a maximum drop of 21 volts. This resulted in a loss of candle power amounting to 50 per cent. The illumination obtained from the new installation fell so far short of what had been anticipated that the proprietor became very much dissatisfied with the new service, since he laid the blame entirely upon the central station.

In previous investigations of voltage conditions upon the circuits of central stations, the authors have encountered a number of cases where considerable interior drop existed. The amount of this drop was determined by changing the load conditions and noting the change of voltage. The resultant data do not truly indicate the interior drop, since the effect extends clear back to the primary. The following data on such cases are given without any attempt at averaging.

TABLE VI

No.	Volts Drop	Lighting Load kw.	Volts Drop per kw.
1	4.0	3.0	1.3
2	2.0	1.0	2.0
3	28.0	1.0	28.0
4	6.0	1.5	4.0
5	26.0	2.6	10.0
6	7.0	2.6	2.7
7	4.0	5.0	0.8
8	4.0	0.24	16.7
9	8.5	11.0	0.8
10	9.0	2.2	4.0
11	3.5	0.6	5.4
12	0.7	0.1	7.0
13	20.0	1.8	9.0
14	1.0	0.24	3.1
15	4.0	0.2	20.0
16	7.0	5.0	1.4
17	3.0	0.85	3.5
18	4.0	0.5	8.0

CONCLUSION

The community of interest which exists between the central station and the electrical manufacturer makes it necessary that they co-operate to supply the ultimate consumer with complete, satisfactory and economical electric service.

The several tables of data bring out the fact that the attention given to the wiring of buildings is too often superficial. The problem of supplying each customer with that electric service which will best fit his individual requirements is one which each branch of the electrical industry should aid in solving because it has, directly or indirectly, an affect on the progress of all.

If the condition found in this investigation, viz., an average interior drop of at least two volts, is indicative of general conditions throughout the country, then, due to this difference of two volts between the voltage rating and the voltage of the circuit

(1) The central stations are losing about 3 per cent of their current sales to lighting customers. If the decrease in revenue is proportional to the decrease in wattage the total loss for all the stations of the country amounts to approximately $8,000,000 per year.

(2) The lighting customers are losing about 7 per cent of their rightful candle-power.

Aside from the loss in candle-power, customers experience a variation in brightness of lamps which depends upon the maximum drop rather than on the average drop.

The quality of electric service, as typified by the satisfaction resulting from the use of domestic appliances, is somewhat impaired, due to the relatively greater drop caused by these appliances.

The authors do not wish to make any general recommendations as to methods of eliminating the losses of candle-power and revenue caused by interior voltage drop, yet it would seem that great benefit would accrue from taking this drop into consideration in the co-ordination of the ratings of lamps, appliances, etc., with the voltage of the circuits *at the point where they are to be used.*

APPENDIX

The authors presented before this Association last year a paper which dealt with the general subject of voltage conditions. In this paper were shown the losses in candle-power and revenue which result from the operation of lamps at less than their normal rated voltage. A summary was given of the conditions which had been found upon the circuits of 82 central stations in cities ranging in population from 1000 to 50,000.

In the year just past, several more such investigations have been made and as a matter of possible interest the results of these later investigations are given, together with an amplified summary of the data previously published. (See Table IX.)

Several of the central stations visited a year or so ago, have been revisited and in most cases a considerable change for the better in voltage conditions has been found. The following table shows the amount of this change:

TABLE VIII

No.		Per cent Diff. between Max. and Min. Line Voltage		Per cent Voltage loss in Distribution		Voltage Conditions of Lamp Operation	
Old	New	Old	New	Old	New	Old	New
43	126	10	8	5.2	3.7	4 volts under voltage	2 volts under voltage
44	128	6	7	3.6	7.7	4 volts under voltage	O.K.
47	118	12	10	6.5	1.8	3 volts under voltage	2 volts under voltage
54	103	7	4	5.0	6.0	*12 volts under voltage	O.K.
57	125	8	3	2.8	2.2	3 volts under voltage	2 volts under voltage
60	122	13	14	5.2	2.2	8 volts under voltage	2 volts under voltage

*220 volts

TABLE IX

VOLTAGE CONDITIONS UPON CIRCUITS OF CENTRAL STATIONS

No.	Private or Municipal	Population	Kw. Capacity	Phase	Cycles	Voltage Pri. Sec.	Method of Regulation	Line Voltage During Lighting Hours			Dif. Max. and Min. of Ave.	Drop in Percentage of Plant Voltage		Lamp Voltage	Lamps Burning		Station Voltmeters	
								Max.	Min.	Ave.		Max.	Ave.		Volts Under-voltage	Volts Over-voltage	Volts High	Volts Low
1	Pri.	130,000	9,000	3	60	2,300/115	Auto.	123	109	117	12	11	4.1	113		4	O.K.	
			3,500	..	0	250-3W	Auto.	130	110	120	17	8	2.0	120	O.K.		O.K.	
2	Pri.	1,800	150	2	60	1,100/104	Hand	110	97	105	12	13	6.3	110	5			3
3	Pri.	6,100	320	3	60	1,150/115	Hand	118	109	112	8	7	5.1	115	3		1.5-2	
4	Pri.	2,100	130	..	0	220-3W	Hand	115	108	111	6	7	4.3	117	6		3	
5	Pri.	1,300	200	1	60	2,300/115	Hand	129	121	125	6	6	4.0	125	O.K.		1 O.K.	
6	Pri.	9,000	500	3	60	2,300/115	Auto.	121	106	117	13	12	2.5	114		3	3 O.K.	
			150	..	0	220												
7	Pri.	8,000	300	3	60	2,300/115	Auto.	117	105	112	11	9	3.4	117	5		4 O.K.	
8	Pri.	1,200	100	3	60	2,300/115	None	112	106	107	6	7	6.1	114	7		3	
9	Pri.	3,000	150	..	0	220-3W	Hand	125	99	108	24	12	4.4	112	4		5	
10	Mun.	5,000	125	2	60	2,300/115	Hand	113	104	107	8	11	7.0	114	7		4 O.K.	
11	Pri.	2,500	150	1	60	1,100/110	Hand	116	98	106	17	15	8.6	112	6		4	2
12	Mun.	2,100	150	1	60	2,200/110	Hand	113	102	105	10	8	5.5	112	7		2	
13	Pri.	2,800	275	1	60	2,300/115	Auto.	122	112	116	9	5	3.9	112		4		3
14	Mun.	3,100	200	2	60	2,300/110	Hand	117	108	112	8	8	4.5	112	O.K.			1
15	Pri.	2,800	100	..	0	220-3W	Hand	235	170	196	33	..	..	120	44/22		5	
16	Pri.	2,500	300	3	60	2,300/115	Hand	115	100	106	14	16	10.4	106	O.K.			1
17	Mun.	4,500	400	3	60	2,200/110	Hand	111	103	106	8	6	3.6	115	0			4
18	Pri.	10,000	900	3	60	2,200/110	Auto.	111	106	109	5	7	4.4	112	3			3
19	Pri.	1,200	60	1	60	2,200/110	Hand	116	104	112	11	13	5.5	117	5			5

23	Pri.	1,900	125	3	60	2,300/115	Hand	131	106	118	21	15	5.4	114		4		7
24	Pri.	2,500	225	1	133	1,100/110	Hand	110	98	106	11	11	3.6	112	6		2-5	
25	Pri.	1,700	150	2	60	1,100/110	Hand	108	100	104	8	7	3.7	108	4		4	2
26	Pri.	7,000	350	2	60	2,200/110	Hand	113	106	109	6	7	4.4	110	1		3	
27	Mun.	2,500	210	..	0	250-3W	Hand	124	106	110	16	13	10.5	127	17		5	
28	Pri.	1,800	100	1	60	1,100/110	Hand	110	102	106	8	11	7.0	118	12		6	
29	Mun.	3,000	150	1	60	2,300/115	Auto.	116	102	111	13	13	5.1	117	6		2	
30	Pri.	2,400	150	..	0	125	Hand	123	100	112	21	21	11.2	120	8			3
31	Mun.	1,800	135	..	0	120	Hand	122	112	115	9	14	11.5	125	10		3	
32	Mun.	11,000	1,000	3	60	2,300/115	Hand	115	104	109	10	9	4.4	104		5	2	
33	Pri.	27,000	2,750	3	60	2,300/115	Auto.	113	109	110	4	5	4.4	115	5		2 O.K.	
34	Pri.	50,000	675	3	60	2,200/110	Auto.	111	104	108	6	7	3.6	110	2		O.K.	
35	Pri.	8,000	450	3	60	2,300/115	Auto.	117	107	112	9	11	5.1	115	3		2	
36	Pri.	34,000	1,500	3	60	2,300/115	Hand	119	107	115	10	11	4.2	117	2		4 O.K.	
37	Pri.	16,000	500	3	60	2,300/115	Auto.	113	110	111	3	4	3.5	112	1		O.K.	
38	Pri.	1,600	160	1	60	1,150/115	Hand	118	114	116	3	5	3.4	115		1		2.5
39	Pri.	3,900	195	2	60	2,200/110	Auto.	103	93	98	10	7	2.0	110	12			2
40	Pri.	2,000	125	1	133	1,100/110	Hand	113	105	109	7	6	2.7	110	1		2	
			30	..	0	110	Hand											
41	Pri.	3,800	250	1	60	1,100/110	Auto.	113	110	111	3	6	4.6	112	1			2
42	Mun.	3,000	190	1	133	1,100/110	Hand	112	100	105	11	13	8.3	110	5			4.5
43	Pri.	15,000	600	3	60	2,300/115	Auto.	116	105	110	10	10	5.2	114	4		3	
44	Pri.	13,000	700	3	60	2,200/110	Hand	111	105	108	6	6	3.6	112	4		4 O.K.	
45	Pri.	1,900	185	3	60	1,100/110	Hand	113	104	107	8	9	6.1	112	5		4	
46	Mun.	1,600	190	3	60	2,200/110	Hand	106	95	100	11	11	4.7	115	15		5	
47	Pri.	10,000	675	2	60	2,200/110	Auto.	121	107	114	12	12	6.5	117	3		O.K.	
48	Pri.	5,600	300	1	133	1,100/110	Hand	118	103	109	14	13	7.1	114	5			5.5
49	Mun.	7,200	300	3	60	2,300/115	Hand	114	105	110	8	11	5.2	115	5		3.5	
50	Pri.	4,300	150	1	60	2,200/110	Hand	115	109	111	5	7	5.1	112	1		2	
51	Mun.	4,200	400	3	60	2,200/110	Hand	113	105	109	7	8	4.4	114	5		6	
52	Pri.	4,800	250	3	60	2,200/110	Hand	112	106	108	6	7	5.3	110	2		3	
53	Mun.	9,100	350	1	60	1,100/102	Auto.	103	95	98	8	9	5.8	104	6			2
54	Pri.	2,700	175	..	0	250	Hand	236	221	228	7	8	5.0	240	12/6		7	
55	Mun.	8,300	600	3	60	2,300/115	Hand	115	107	109	7	8	6.8	115	6		2.5	
56	Pri.	3,100	200	1	60	2,200/110	Hand	110	96	104	13	14	7.1	125	21		4	

No.	Private or Municipal	Population	Kw. Capacity	Phase	Cycles	Voltage Pri. Sec.	Method of Regulation	Line Voltage During Lighting Hours Max.	Min.	Ave.	Dif. Max. and Min. of Ave.	Drop in Percentage of Plant Voltage Max.	Ave.	Lamp Voltage	Lamps Burning Volts Under-voltage	Volts Over-voltage	Station Voltmeters Volts High	Volts Low
57	Pri.	5,000	250	3	60	1,100/110	Auto.	110	102	105	8	6	2.8	108	3		10	
58	Mun.	5,000	2,260	2	125	1,100/110	Hand	112	105	108	7	9	6.1	110	2			2
59	Pri.	4,500	340	2	60	2,200/110	Hand	112	104	109	7	10	5.7	118	9		3	
60	Pri.	6,000	325	3	60	2,300/115	Hand	119	105	109	13	9	5.2	117	8			3.5
61	Pri.	80,000	3,000	2	60	2,000/100	Auto.	103	95	98	8	7	4.8	100	2		O.K.	
62	Mun.	3,500	175	2	60	2,300/115	Hand	124	115	119	8	6	2.7	120	1			3
63	Mun.	2,400	113	2	60	2,200/110	Hand	118	106	111	11	14	9.6	114	3			3.5
64	Pri.	3,600	560	3	60	2,400/120	Auto.	135	113	118	19	6	1.3	120	2		O.K.	
65	Mun.	5,300	750	3	60	2,400/120	Auto.	125	113	119	10	10	4.8	112		7	2.5	
66	Pri.	41,000	2,100	3	60	2,300/106	Auto.	109	102	106	7	7	3.6	108	2		O.K.	
			300	..	0	220-3W	Auto.											
67	Pri.	1,500	140	..	0	220-3W	Hand	118	99	108	18	15	6.7	112	4		1.5	
68	Mun.	2,500	225	3	60	2,300/115	Auto.	119	114	117	4	6	2.9	117		O.K.	1	
69	Pri.	1,800	100	..	0	220	Hand.	223	198	213	12	15	9.9	220	7/3.5		2-3	
70	Pri.	4,400	300	..	0	220-3W	Auto.	116	98	112	16	6	2.0	116	4		5-5	
71	Mun.	1,700	100	2	60	1,100/110	Auto.	114	107	112	6	5	2.2	115	3		O.K.	
72	Pri.	21,000	1,500	3	60	2,300/115	Auto.	117	107	112	9	11	5.1	115	3		O.K.	
73	Pri.	5,400	600	3	60	2,200/110	Auto.	113	104	109	8	9	6.8	114	5		O.K.	
74	Mun.	3,000	150	3	60	1,100/110	Hand	110	100	107	9	11	4.2	110	3			1
75	Pri.	3,400	150	3	60	1,100/110	Hand	107	99	103	8	10	5.2	106	3		1	
76	Pri.	2,500	75	3	60	1,150/115	Hand	120	109	114	10	9	4.4	118	4		O.K.	
77	Pri.	4,400	125	3	60	2,300/115	Hand	113	106	110	6	6	2.8	113	3			2
78	Pri.	25,000	475	3	60	2,300/115	None	125	97	112	22	18	5.1	115	3		2	
79	Mun.	2,600	480	3	60	2,200/110	Hand	116	106	112	11	4	0.7	115	3		O.K.	
80	Pri.	1,800	130	1	60	2,200/110	Hand	113	104	108	8	11	6.1	117	9		3.5	
81	Pri.	9,000	100	3	25	2,200/110	None	106	100	102	6	..	..	115	13		None	
82	Mun.	3,700	200	3	60	2,200/110	Hand	116	104	110	11	9	3.5	111	1			2
83	Mun.	4,000	200	3	60	2,200/110	Auto.	110	104	108	6	7	4.3	110	2		2-3	
84	Pri	3,000	125	3	60	2,400/110	Hand	122	119	120	3	4	4.9	121	3	1	O.K.	
			200	..	0	220-3W	Hand	132	114	124	15	12	8.2				1-2	

85	Mun.	3,000	375	3	60	2,200/110	Auto.	115	109	113	5	6	3.2	111		2		2
86	Pri.	1,000	50	..	0	110	Hand	116	110	114	5	11	7.3	110		4		4
87	Pri.	3,000	300	1	133	1,100/110	Auto.	108	97	103	11	6	2.0	105	2		O.K.	
88	Pri.	8,100	500	3	60	2,200/110	Auto.	108	101	104	7	10	7.0	112	8		8-1	
89	Pri.	1,000	40	..	0	110	Hand	107	96	100	11	15	11.5	110	10		2	
90	Pri.	1,000	130	1	60	2,200/110	Hand	114	102	110	11	14	8.4	110		O.K.		7-8
91	Pri.	9,700	1,000	3	60	2,200/110	Hand	121	95	111	23	18	4.5	114	3		1	
92	Pri.	3,100	250	3	60	2,300/115	Auto.	114	97	112	15	15	2.1	114	2			4
93	Pri.	5,000	210	3	60	2,200/110	Auto.	120	107	115	11	11	4.2	110		5	5-5	
94	Pri.	35,000	500	3	60	2,300/115	Auto.	119	106	112	12	17	12.5	115	3		Not Ch'ked	
95	Pri.	2,400	210	..	0	440-3W	Hand	236	210	224	11	13	6.7	230	6/3		4-3	
96	Pri.	1,100	100	1	133	1,100/110	Hand	108	97	102	11	10	5.6	104	2		1 O.K.	
97	Pri.	1,500	100	1	125	1,100/110	Hand	110	101	106	8	8	3.3	114	8			2-3
98	Mun.	3,500	200	1	133	2,300/115	Hand	116	84	110	29	7	2.7	114	4			1
99	Pri.	1,400	125	3	60	2,200/110	Hand	119	99	112	18	17	5.9	112		O.K.	1	
100	Pri.	1,200	112	3	60	2,200/110	Auto.	115	111	113	4	4	1.7	112		1		3
101	Pri.	14,000	800	3	60	2,200/110	Auto.	120	103	112	15	9	1.9	113	1			1
			300	..	0	220-3W	Auto.											
102	Pri.	2,300	470	3	60	2,300/115	Auto.	132	119	122	11	5	2.4	114		8	O.K.	
103	Pri.	2,700	182	..	0	250	Hand	239	229	235	4	12	6.0	235		O.K.	2-2	
104	Pri.	9,000	1,100	3	60	2,300/115	Auto.	116	101	113	13	14	4.5	115	2		1	
105	Mun.	4,000	490	3	60	2,300/115	Hand	115	109	112	5	5	2.6	110		2	5	
106	Pri.	6,000	208	1	125	1,150/115	Hand	111	108	109	3	8	5.1	112	3			4-4
107	Mun.	6,000	350	3	60	2,200/110	Hand	114	101	110	12	10	3.4	112	2			0.5
108	Pri.	25,000	1,100	3	60	2,200/110	Auto.	116	102	109	13	9	4.2	114	5		O.K.	
109	Pri.	8,500	1,100	3	60	2,200/110	Auto.	112	101	110	10	17	9.8	116	6		O.K.	
		4,000						115	106	110	8	13	9.8	114	4			
		6,600						115	105	110	9	14	9.2	114	4			
110	Mun.	16,000	430	..	0	500-3W	Hand	238	204	213	16	17	13.1	220	7/3.5		4-4-2	O.K.
111	Pri.	3,000	265	1	133	1,100/110	Auto.	117	109	113	7	5	1.9	112		1	O.K.	3
112	Pri.	4,200	90	1	133	1,100/110	Hand	118	94	110	22	17	7.9	112	2		O.K.	6
113	Pri.	5,000	500	3	60	2,200/110	Auto.	115	102	110	12	11	4.0	112	2			2-2
114	Pri.	1,200	265	3	60	2,200/110	Hand	115	101	109	13	9	7.4	112	3		3	1
115	Mun.	2,000	135	..	0	115	Hand	122	115	117	6	10	8.3	120	3			1
116	Pri.	5,000	395	2	60	2,300/115	Auto.	122	106	113	14	13	6.0	115	2		1-1-0.5	2.5

No.	Private or Municipal	Population	Kw. Capacity	Phase	Cycles	Voltage Pri. Sec.	Method of Regulation	Line Voltage During Lighting Hours Max.	Min.	Ave.	Dif. Max. and Min. of Ave.	Drop in Percentage of Plant Voltage Max.	Ave.	Lamp Voltage	Lamps Burning Volts Under-voltage	Volts Over-voltage	Station Voltmeters Volts High	Volts Low
117	Pri.	9,000	520	3	60	2,200/110	Hand	116	102	109	13	11	4.7	112	3			3-12
118	Pri.	10,000	650	2	60	2,200/110	Auto.	118	107	114	10	8	1.8	116	2		3-3-2	
119	Pri.	12,000	500	3	60	2,200/110	Auto.	116	114	115	2	6	6.3	116	1		2-2-1	O.K.
			740	..	0	220-3W	Hand	121	113	115	7	7	5.7					O.K.
120	Mun.	2,000	150	..	0	220	Hand	242	205	217	17	18	13.2	220	3/1.5		5	
121	Pri.	1,700	60	..	0	220	Hand	224	215	222	4	7	3.5	220		1	2	
122	Pri.	6,100	275	3	60	2,200/110	Hand	115	100	110	14	11	2.2	112	2			2
123	Mun.	1,300	140	1	60	2,200/110	Hand	114	103	112	10	9	0.9	115	3			3
124	Pri.	5,100	230	..	0	220	Hand	225	190	209	17	16	7.4	220	11/5.5		O.K.	3.5
125	Pri.	5,000	250	3	60	1,100/110	Auto.	111	108	110	3	4	2.2	112	2			3-2
126	Pri.	15,000	1,500	3	60	2,300/115	Auto.	113	104	110	8	9	3.7	112	2		O.K.	
127	Pri.	20,400	10,000	2	60	2,300/115	Auto.	132	100	121	26	7	3.0	120		1	Not Ch'ked	
128	Pri.	12,900	1,000	2	60	2,300/115	Auto.	114	106	110	7	11	7.7	110			1	
129	Pri.	3,000	225	2	60	2,300/115	Hand	111	108	110	3	7	5.2	115	5			2
130	Pri.	5,100	500	3	60	2,300/115	Auto.	117	102	110	14	14	8.4	114	4		1	
131	Pri.	1,050	112	..	0	220	Hand	228	214	221	6	6	3.0	230	9/4.5		O.K.	
132	Mun.	1,600	125	3	60	2,300/115	Auto.	119	115	117	3	4	2.8	116		1		5
133	Mun.	5,700	200	1	133	2,200/110	Hand	113	102	109	10	11	4.3	112	3			2
	Average										10.4	9.9	5.2		3.4			

DISCUSSION

Mr. Preston S. Millar, New York City: I want to express appreciation of this work which Mr. Campbell has been doing with Mr. Cooper for the past two years in making these data available. I would also like to ask one question. In computing this loss of three per cent, has a liberal estimate been figured in for the drop during different hours of the day?

Mr. Cooper: We thought that our load conditions would approximate the average load during the day in general, rather than the maximum demand, so that whatever drop we found would be the average for the whole day, rather than for the peak load. Under those conditions, the three per cent loss of current sales would apply to the average annual values rather than just the loss of the peak load.

Mr. H. K. Hansen, St. Louis: I notice with much interest a paragraph regarding architects. We have great trouble in St. Louis from the same cause, and I would like to find out, if possible, how other cities get around it. In a great many cases we find that the wiring plans, as laid out by the architects do not specify definitely the number of lamps and we have difficulty in keeping the contractors from cutting down on the number by afterwards talking with the prospective builder and putting the work in on a basis that was not originally contemplated. The result is that when the wiring is inspected for carrying capacity it is not inspected from the plans, and when the actual installation is at last made, there are more lamps on the circuit and more apparatus than they can take care of with the different sizes of wire that have been installed, while gradually they take on other apparatus which increase the load. We have had a hard time keeping them up to the proper size.

The Chairman: It seems to me that is a question you might take up with some of the members privately, Mr. Hansen.

Mr. Hansen: Perhaps I can. I thought I might draw out a little information.

The Chairman: Will there be any further discussion, gentlemen? We will close the session by listening to the report of the Committee on Measurements and Values. Dr. A. E. Kennelly is not here, but Dr. Steinmetz has kindly consented to present the report and to make a few comments on it.

REPORT OF THE COMMITTEE ON MEASUREMENTS

During the past year, considerable progress has been made by engineering societies towards unifying and simplifying the standards, units, and terminology of power. At the present time we have the following units of power in current engineering literature:

(1) The horse power, as used in Great Britain and America (746 watts)
(2) The horse power, as used on the continent of Europe (736 watts)
(3) The poncelet (981 watts)
(4) The British thermal unit per hour (0.2928 watt)
(5) The kilogram calorie per hour (1.162 watt)
(6) The boiler horse power (9804 watts)
(7) The watt, with its decimal multiples the hectowatt, kilowatt and myriawatt
(8) The water horse power of 3960 gallon-ft.-per-min. (746 watts)

Nos. (4), (5) and (6) are used in conjunction with steam engineering.

The last edition of the Standardization Rules of the A. I. E. E. recommends "that the kilowatt, instead of the horse power, be used generally as the unit of power," (edition of August, 1911, Appendix F).

The Unofficial Conference of the International Electrotechnical Commission at Brussels, in August, 1910, recommended "that both electrical and mechanical powers be expressed in international watts" (I. E. C. Publication No. 8, pp. 48 and 49). This recommendation was confirmed at the official meeting of the Commission at Turin, in September, 1911 (I. E. C. Publication No. 2, pp. 80 and 81). Similar recommendations appear in the reports of the I. E. C. special committees on "Rating" and on "Prime Movers," held in January, 1913, at Zurich, Switzerland (I. E. C. Publications Nos. 20 and 21).

The Bureau of Standards, in its Circular No. 34, of 1912, also recommends that the kilowatt be used instead of the horse power.

It is very probable that the term "horse power" will eventually disappear completely from engineering literature. It is a crude makeshift that has outlived its usefulness. James Watt made measurements on the power developed by certain selected brewery horses engaged in pumping water.[1] Having ascertained their effective output under these conditions, he purposely and admittedly added 50 per cent, for friction allowance and good measure, thus arriving at his 550 foot-pounds per second, in order to make sure that the power of his new steam engines, stated in such "horse power," should be beyond dispute. It is known, moreover, that the power which any animal can develop varies widely with the time during which the power has to be maintained.[2]

On December 13, 1913, a joint meeting was held, in New York City, of Standards Committees from the American Society of Mechanical Engineers and the American Institute of Electrical Engineers. At this meeting the following resolutions were unanimously passed:

WHEREAS, the "myrowatt" or "myriawatt" was suggested by Mr. H. G. Stott as a convenient unit of power only 2 per cent larger than the most recently determined values of the "boiler horse power," and

WHEREAS, a paper setting forth the advantages of the use of the "myriawatt" as a unit of power in dealing with the performances of steam boilers, steam engines, gas engines, steam and water turbines was read by Messrs. H. G. Stott and Haylett O'Neill before the annual convention in Boston of the American Institute of Electrical Engineers in June, 1912, was discussed, and was published in the Proceedings of the Institute, and

WHEREAS, the American Society of Mechanical Engineers has appointed a special committee to confer with the Standards Committee of the American Institute of Electrical Engineers upon this unit, as presented in the said paper, be it

Resolved, (1) That the two committees in joint session recommend to their respective societies the use of the "myriawatt" as a unit of thermal or mechanical power, as indicated in the above-mentioned paper.

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(1) Circular of the Bureau of Standards No. 34, June, 1912, "The Relation of the Horse Power to the Kilowatt."

(2) "An Approximate Law of Fatigue in the Speeds of Racing Animals," by A. E. Kennelly. *Proc. Am. Acad. of Arts and Sciences,* Vol. XLII, No. 15. Dec., 1906.

(2) That the two committees also jointly recommend to their respective societies the exclusive use of the "myriawatt" in connection with boilers, producers, turbines and engines and discontinuance of the use of the term "boiler horse power."

(3) That Mr. C. O. Mailloux, as representing Mr. H. G. Stott on the special committee on "Prime Movers" recently appointed by the International Electrotechnical Commission, which committee is scheduled to meet at Zurich, Switzerland, on January 18, 1913, shall be and hereby is requested to bring these joint resolutions formally to the notice of that body in Zurich.

(4) That the two committees jointly recommend that in writings and publications the "myriawatt" and "myriawatt-hour" be abbreviated to mw. and mw-hr. in conformity with the existing abbreviations kw. and kw-hr. for kilowatt and kilowatt-hour respectively.

The governing boards of the two engineering societies represented in joint committee, endorsed and published the above resolutions.

There has since been some discussion of the matter indicating that some engineers prefer to retain the older thermal power units in dealing with steam boilers.

The myriawatt is not in itself preferable to the kilowatt as a unit of power; but it is a self-explanatory decimal multiple of the watt. Both the "Standard" dictionary and Worcester's dictionary give "ten thousand" as one of the meanings of the word "myriad." The "myriameter," "myrialiter" and myriagram" are well known. although relatively less used, units in the metric system.

The watt is primarily a dynamical or mechanical unit of power, not an electrical unit. It is the power which a kilogram-mass absorbs if accelerated uniformly 1 meter per second each second, when its speed is just 1 meter per second; i. e., at the end of the first second of such acceleration. The myriawatt happens to be very nearly the same as the "boiler horse power"; so that, by the use of the term in place of boiler horse power, a unification and simplification of steam-generator units is effected. There is something incongruous in making measurements of the power output of a turbo-generator in one unit, and of the power input in another unit, when the efficiency or ratio of the two is desired. It is true that the output is electric and the input thermal; but power is power whether electric or thermal, and is most simply expressed in terms of one and the same unit. Income and

expenditure might just as logically be expressed in terms of marks and dollars respectively.

An effort has recently been made in Great Britain to revive the use of the term "kelvin" for a "kilowatt-hour" as a unit of energy. In 1892, the British Board of Trade officially proposed this use of Lord Kelvin's name for the kilowatt-hour, which has generally been known in England as a "Board of Trade Unit." In England the term "kelvin" has been very little used for this unit, and in this country the term "kilowatt-hour" has always and everywhere been used commercially for this unit. In view of the fact that it would be extremely difficult to displace the kilowatt-hour in America for the non-self-explanatory term "kelvin," and that the term watt-hour would, in any case, have to be retained as the unit, one thousand of which would be equal to one "kelvin," it is to be hoped that this use of Lord Kelvin's name will not receive endorsement in official circles. There is great need of his name in relation to an electrostatic unit.

Respectfully submitted,

A. E. KENNELLY, *Chairman.*

DR. CHARLES P. STEINMETZ: The report first repeats the demand for a standardization of the units of power made last year, and draws attention to the variegated collection of power units which we have now.

Various attempts have been made for a number of years to make power measurements more systematic by introducing the kilowatt as the unit of power. The standardization rules of the American Engineering Institute have tried this over and over again, not always with success, because the buyer, the user, knows horse power, or believes he knows it, but does not know kilowatts. While generators have universally been rated in kilowatts, motors are still largely rated in horse power to accommodate the customer, so that he knows, or believes he knows, what he gets. (Laughter.)

Then when the International Electrical Commission began the work, it naturally adopted the kilowatt as the unit of power, electrical as well as mechanical. I might incidentally remark that the same energy measure is very largely used to-day in chemistry. The old calorie is not the general unit of chemical

energy any more, it is the kilowatt-second. There is a difference which is really progressive.

As regards the term horse power, Dr. Kennelly hopes that it will eventually disappear. Well, it may, in the future. The term horse power does not mean the power which a horse can deliver. It belongs in a class with several familiar phrases of which, in electric lighting, the 2000-c-p. arc light is one (Laughter.)

An attempt to introduce the metric system into mechanical engineering has been made during the last year or two by combined standardizing committees of the American Society of Mechanical Engineers and the American Institute of Electrical Engineers, and a number of resolutions were agreed upon regarding the establishment of the myriawatt as the mechanical unit in place of the term horse power. This was agreed upon by the committees of the two national associations, and then referred to the International Electric Commission. I may remark that I do not find in this report a recommendation by Dr. Kennelly in favor of the adoption of the myriawatt, hence I do not know whether he favors it or not. In general there is a good deal to be said in favor of it, because it brings us a little nearer to a more consistent system of units. On the other hand, it rather appears as if they introduced such a make-shift as a myriawatt merely because it is approximately equal to a boiler horse power. It might just as well remain a kilowatt. In Chicago and other places they use the word "megowatt." At the stations which you are to visit to-morrow afternoon I believe, the rating is, or should be, not in kilowatts but in megowatts—200 megowatts or 200,000 kilowatts. When we speak of the watt we must realize that it is not inherently an electric unit; it is a mechanical unit of power. It is merely the metric system, which has been adopted and is in general use also in mechanical engineering.

In Great Britain an attempt has been made to introduce the term "kelvin" for a kilowatt-hour in honor of Lord Kelvin. That has not been favored, because the names of prominent scientists and engineers are used for the absolute units of measurement, as ampere, volt and watt. Kilowatt-hour, however, is not an absolute unit, because the second and not the hour is the unit. The kilowatt-second would be the unit. The kilowatt-hour is, after all, something like the railwayman's measure of

acceleration in miles per hour per second. While for convenience such units are used and are quite legitimate, it is not desirable to have such a unit, as acceleration in miles per hour per second.

As I have said, I do not see any particular recommendation regarding the new unit, and I believe most of you will probably agree with me that it is very desirable not to have any more new units, because we already have an ample supply. It is better also to use the longer expression, to speak of kilowatt-hours, than it is to learn a new name, and to have to begin to teach everybody with whom we come in contact the meaning of the new name. (Applause.)

(Adjourned.)

SECOND TECHNICAL SESSION

THURSDAY MORNING, JUNE 5

THE CHAIRMAN, MR. W. C. L. EGLIN: The meeting will please come to order. The first business this morning is the Report of the Committee on Prime Movers, Mr. I. E. Moultrop, Chairman.

REPORT OF THE COMMITTEE ON PRIME MOVERS

WATER POWER

(See Report on Turbines, Hydro-Electric Sessions, pages 100 to 130, inclusive.)[1]

STEAM POWER

Your Committee is pleased to record some interesting developments with the steam turbine during the past year, as well as the development of a full line of steam turbine-driven auxiliaries.

DEVELOPMENTS IN THE STEAM TURBINE DURING THE PAST YEAR

The Committee has received statements from two turbine manufacturers, as follows:—

General Electric Company

"During the past year or more the development of Curtis turbines, built by the General Electric Co., has been in the direction of higher speeds and a larger number of stages than were heretofore employed, with the object of securing higher efficiency. This has made desirable some mechanical changes. The vertical design heretofore generally used for all large sizes is particularly well adapted to the speeds of 720 and 750 rev. per min. At these speeds the machines are relatively short, with reference to their diameter, and with the large bucket area afforded give large limits of capacity without congestion at the low-pressure end.

"The high-speed turbine, with a large number of stages, is not adapted to a vertical construction, and machines of this type are being built with horizontal shafts.

"The available speeds for large horizontal-shaft machines are 1200, 1500 and 1800 rev. per min. Machines of 20,000-kw. capacity are on order, and will be put into commercial service in a few months. Designs of larger machines have been completed.

[1]The Water Power portion of this Report was presented before the Hydro-Electric Section by Mr. J. E. Moultrop for J. F. Vaughan.

"In the arrangement of buckets and nozzles the present practise is the result of experience acquired in building turbines of the impulse type, in this country and abroad, and, in general, consists of the use of one or more of the usual Curtis stages with two rows of buckets, followed in some cases by stages, each containing a single Curtis wheel, with one row of buckets. Turbines of this type do not require balance pistons, as they are free from end thrust. Machines of this design have been carefully tested and show remarkable results, superior, in fact, to anything heretofore produced.

"All large machines are equipped with removable nozzles, and in most cases the diaphragms are split horizontally to permit ready removal.

"These machines, like all Curtis turbines, are well adapted to take advantage of the best steam conditions obtainable. The design permits of correct expansion of steam from the highest practical pressures to the best possible vacuum, giving the greatest temperature range. In the matter of vacuum particularly, the low-pressure buckets afford ample area for large volumes of steam without congestion. High superheat, *i. e.,* 150 to 200 deg. fahr., is desirable and improves the efficiency.

"In the matter of small turbines, both in connection with generators and for pumps or other mechanical drive, considerable work has been done. The efficiency, of course, varies with the capacity and speed. Under the usual non-condensing conditions 58 per cent of available energy is transformed into useful work."

Westinghouse Machine Company

"The Westinghouse Machine Co. is pleased to report a particularly active year in the turbine field, largely the result of previous development work, with respect to size and application. This is particularly true of large turbines, there being at the present time on order or under construction at the shops 16 units of 10,000 kw., or greater rating, two of them having a continuous capacity of 20,000 kw. Several pending negotiations involve the construction of units of even greater capacity, which will be the largest yet built. Such machines will be of the so-called cross-compound type, consisting of two separate sections, as far as the steam and electrical parts of the unit are concerned. For 60-cycle service, for instance, the high-pressure

section would have a capacity of about 15,000 kw., and operate at 1800 rev. per min., expanding the steam from throttle conditions to about atmospheric pressure or slightly greater at rating. The low-pressure section, receiving exhaust from the high pressure after the moisture due to expansion is removed, would normally carry the remaining 15,000 kilowatts, operating at 720 or 900 rev. per min. Both sections of the unit will be under the control of the governor and admission valves of the high-pressure portion. Such control results in a variable back pressure on the high-pressure section, an arrangement giving the best efficiency on varying loads, as well as at rating.

"The high-pressure section will be built as a single-flow reaction turbine of particularly good blade proportions. The low-pressure section will also be of the straight reaction type, arranged double-flow in order to take care of the great volumes of steam. By the use of such a design, very low cost per unit of capacity will be retained, and the thermal efficiency of the unit, based on the output at the generator terminals, will be considerably higher than is realized in any other arrangement.

"The general broadening of the turbine field, with respect to type noted above, is particularly apparent at the present time. During the past year, for instance, a bleeder turbine, of 4000-kw. capacity, has been successfully constructed and tested. Non-condensing machines continue to grow in favor, and justly so. Tests conducted at our works during the past year on machines of 1000-kw. capacity, show a Rankine cycle efficiency on the brake horse power basis of approximately 75 per cent. An interesting installation recently completed involves two non-condensing turbines of 3750-kw. capacity, each connected through Westinghouse reduction gears to 250-volt, direct-current generators, the largest yet built. The operation of these large geared machines is highly satisfactory in every respect. When both are in operation, the resulting noise is considerably less than that made by a single 500-kw. alternating-current unit, an indication of the small losses occurring in the gearing. Geared units of smaller size, of which several have been in constant service for over two years, continue to give the original excellent results.

"The small turbine, by which is generally understood exciter sets and power turbines, is being adopted as rapidly as the apparatus which it drives is developed and standardized, power-house

auxiliaries, such as boiler-feed pumps, blowers, etc., offering a wide field for its use. It would seem correct to say that for boiler-feed service in plants above 1500 boiler hp., centrifugal multi-stage pumps, turbine-driven, are the present standard."

Turbines for Station Auxiliary Purposes

Beginning a number of years ago, the small direct-connected steam turbine took its place in the station for driving exciters; later, for driving centrifugal boiler feed pumps and hot-well pumps; and now, for driving blowers. Because of their compactness, general reliability, and the availability of the exhaust for feed-water heating, these direct-connected units bid fair to supersede all other means for driving station auxiliaries.

An impression prevails that these small steam turbines are not as economical as high pressure engines of the same capacity. In order to present a comparison of the efficiencies of such turbine units, as compared with steam engines of corresponding size, the Committee has obtained information from various turbine and engine manufacturers on this point and presents it herewith in the three sets of curves which follow. (Figs. 1, 2 and 3.)

It is a matter of satisfaction to know that, while the turbines in larger sizes are produced by a few of the larger manufacturing companies only, turbines in the smaller sizes are being developed and put on the market by a number of other companies, for use in driving station auxiliaries and for similar purposes.

The Ferranti High Superheat Steam Turbine

Your Committee feels that it would have made a regrettable omission did it fail to mention the significant experiment of Dr. S. Z. de Ferranti, the well-known pioneer in the various branches of the electric-lighting industry. His ingenuity in the practical solution of certain phases of high-tension work proved of exceeding value to the profession. Likewise, his turbine experiments of recent years bid fair to contribute another important achievement, and his success in his last endeavor has been marked enough to be entirely worthy of being directed to your attention. Dr. Ferranti has been working upon a turbine of more than laboratory proportions, having already constructed and operated a machine of 5000-hp. capacity. The fundamental principle is to maintain the steam in a

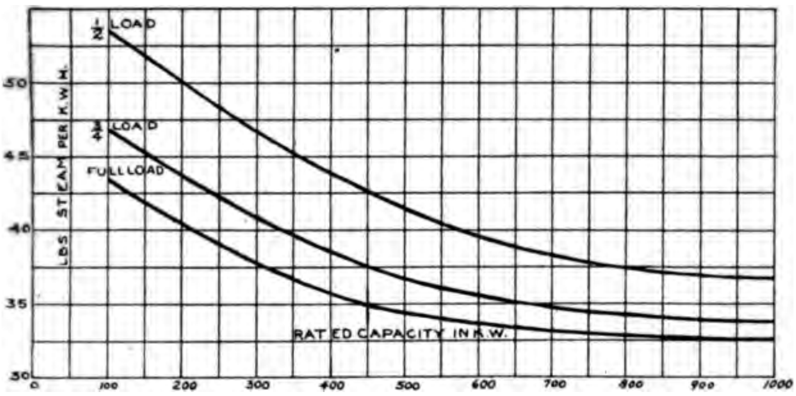

FIG. 1—TURBINE—STEAM CONSUMPTION PER KW-HR. FOR NON-CONDENSING UNITS OF VARIOUS SIZES, RUNNING AT VARIOUS LOADS—STEAM PRESSURE, 150 LB. GAUGE, MFRS. NO. 1

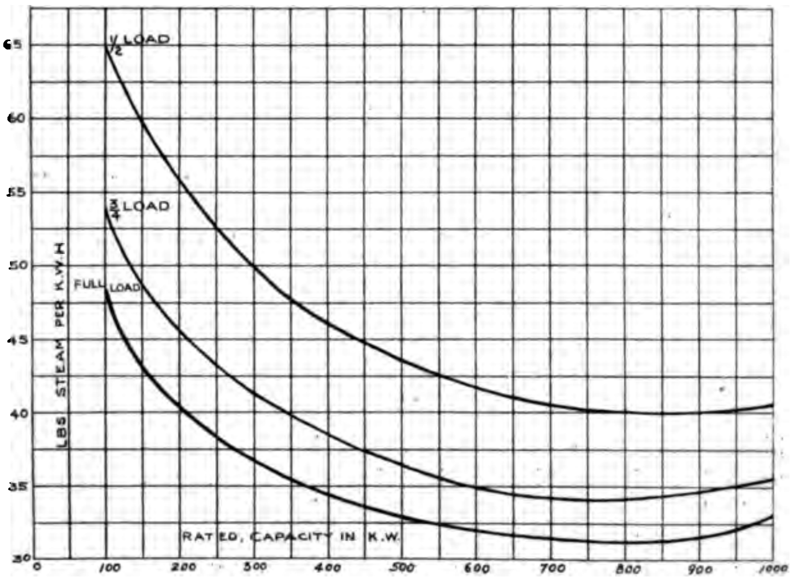

FIG. 2—TURBINE—STEAM CONSUMPTION PER KW-HR. FOR NON-CONDENSING UNITS OF VARIOUS SIZES, RUNNING AT VARIOUS LOADS—STEAM PRESSURE, 150 LB. GAUGE, MFRS. NO. 2

perfectly gaseous state in its travel through the turbine. The steam is initially superheated, and while it is still superheated it is re-superheated before it does work in the second stage. Although the steam is exhausted from the turbine in a superheated condition, the excess heat is reclaimed by a regenerator, situated ahead of the condenser. In its general construction it follows the reaction type, but it is claimed many mechanical innovations have been made which will aid not only in insuring the operating integrity, but will additionally conduce to

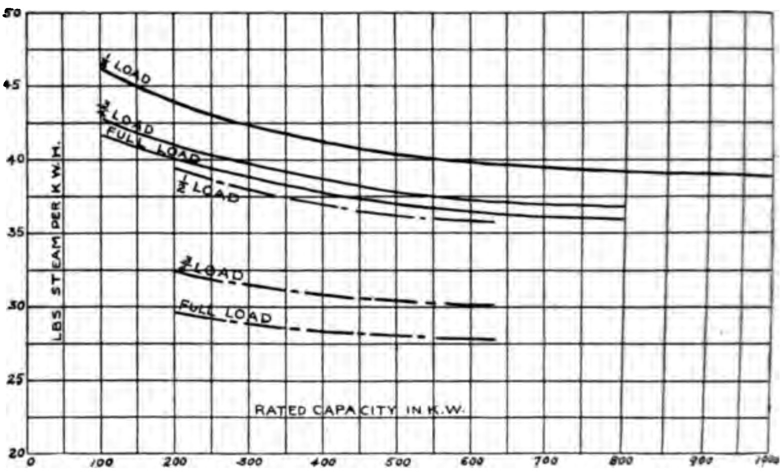

FIG. 3—RECIPROCATING ENGINE—STEAM CONSUMPTION PER KW-HR. FOR NON-CONDENSING RECIPROCATING ENGINE DRIVEN UNITS OF VARIOUS SIZES, RUNNING AT VARIOUS LOADS. STEAM PRESSURE, 150 LB.

GAUGE

— SIMPLE ENGINE

— - - — COMPOUND ENGINE

high thermal efficiencies. It is reported that the results of many tests show that it will take less than 6 lb. of steam per steam-brake horse power, and that with a boiler plant efficiency of 85 per cent, as in case of oil burning, the system will have a thermal efficiency of 24 per cent under its designed conditions. Dr. Ferranti made public these remarkable developments in delivering the James Watt Anniversary lecture at Greenock, Scotland, January 16, 1913.

Low-Pressure Steam Turbines

Where low-pressure steam turbines have been used in connection with steam engines a very positive saving has been effected. Quite a number of these units have been installed and have given satisfactory results. The discontinuance of the installation of reciprocating engine units in large power stations has caused the low-pressure turbine to become of minor importance, and manufacturers predict that in a short time the demand for this kind of apparatus will entirely cease. There is, therefore, but little demand for low-pressure steam turbines to-day for central-station service.

An example of what is being done to-day is to be found in the Christian Street Station of the Philadelphia Electric Co., where a 5000-kw. engine with fly-wheel generator is being dismantled and scrapped to make room for the installation of two 15,000-kw. turbines. Practically the only use to-day for low-pressure and mixed-pressure turbines is to be found in steel mills and such manufacturing plants.

High-efficiency Self-contained Steam Units

The Committee's report last year, in discussing engines of this type, such as Stumpf, Wolf, Lenz, Locomobile and Memming, referred to the apparent success which they were meeting abroad, but stated that they did not appear to be adapted to American conditions. Further investigation apparently confirms this conclusion.

Three manufacturers have arranged to construct or import these engines. One manufacturer states that he had arranged to import a certain make of this apparatus, but found that it would not be profitable to do so. Another manufacturer writes: "Some years ago we spent considerable time and money investigating this engine, but, in our judgment, the field is very limited and not suitable for American commissions. While the economy of this engine approaches that of the cross-compound engine, the expense of building it is practically the same as a compound unit, as you have in effect the low-pressure side of a compound engine, operating under full boiler pressure, and with very short cut-off. Furthermore, the reciprocating parts, especially the piston, are very heavy, and, of course, the turning moment is not as good as that of the cross-compound machine."

Another manufacturer, who has acquired the right to manufacture a certain type of engine of this kind, writes: "We have brought this engine to the United States because we are fully convinced that it is the most economical prime mover on the market. Having the exclusive rights in this country, we are in position to sell to our customers a steam engine of the highest order, at the same time enabling them to produce a horse power at the lowest fuel expense to them."

Condenser Design

The advent of the steam turbine has increased the importance of high condenser vacuum to a degree far beyond that which existed when piston engines only were to be considered, and while this fact is generally appreciated by condenser manufacturers, some have been slow to realize that a material change in design is required to properly meet the new conditions.

Condensers are sometimes built following the design of a water-tube boiler, the designer apparently being under the impression that the greater number of times the steam in its passage through the condenser might be brought into contact with the tubes the greater would be the amount of heat extracted. This idea naturally leads to a design having a long steam passage, thickly studded with tubes and interrupted with baffles, through which passage the steam is forced at a very high velocity. This can be done only by a very considerable difference in pressure at the two ends of the passage, with, of course, the higher pressure next to the last stage bucket; and it is the pressure at this end of the steam passage which determines the efficiency of the unit, regardless of what the pressure may be at the other end of the steam passage.

When designers realize that exhaust steam has not the same characteristics as flue gas, and that a condenser should be designed to get the steam to and not through the cooling surface, we will have condenser tubes located far enough from the last row of buckets to permit the steam to free itself from the last row of blades without creating a decided back pressure at that point. Passages of such ample cross section will be provided that the steam will have immediate and free access to all portions of the cooling surface at moderate velocities and without following a tortuous and constricted path around baffles and between tubes;

throughout the condenser dead pockets will be avoided and the entrained air will be swept constantly toward the dry air suction, while the condensation will fall to the bottom of the condenser without undue refrigeration and in the same direction as the general flow of steam.

A lighting company, handicapped with high-priced fuel, might consider itself warranted in replacing its turbines with units of an improved design, having a ten per cent better economy, and yet it is easily possible that the design of the condenser might make more than half this amount of difference in the performance of the unit.

One member company reports that its condenser pressure under the last stage wheel was reduced from 1.4 in. to 0.8 in. by simply removing baffles and opening steam passages among the tubes; and a manufacturer states that it is now possible to design condensers in which the difference in pressure between inlet and outlet will not exceed ¼ in.

When the owner realizes that his coal bill varies somewhere between 5 and 8 per cent with each inch of difference in vacuum he will no longer tolerate a vacuum between one and two inches lower than should be easily attainable with a given temperature of cooling water.

INFORMATION RECEIVED FROM MEMBER COMPANIES

For the purpose of obtaining information on certain specific questions and for bringing out other information of general interest, a circular letter was sent out to about 25 of the more prominent member companies bearing on the following general subjects:

1 New Methods and Devices
2 Flow Meters and Forced Draft
3 Feed-Water Heaters and Feed-Water Heating
4 Deterioration of Steel Stacks
5 Trouble with Turbine Blades

Answers to these questions were received from 14 companies, and from these answers the following is abstracted:—

New Methods and Devices

One large company is installing a permanent set of scales, weighing tanks and pumps, so connected to the feed-water piping

that it will be immediately available for testing any one of the several units in the power house. The organization of the boiler-room force has been so altered that the Fuel Engineer reports to the Chief Engineer, instead of to the Boiler-room Engineer, the theory being that this will render the Fuel Engineer more independent in his recommendations and criticisms and will enable the Chief Engineer to better direct the operation of the boiler room.

Another company has perfected a very ingenious device for removing the fine coal siftings from the pit under the grate. A McClave steam blower has been so piped up that it draws air from a sump in the fine coal pit and discharges into the furnace above the grate. When it is desired to clean out the fine coal pit the coal is scraped into the sump, the blower turned on, and the fine coal is immediately blown into the furnace, where the greater part of it burns before falling to the grate.

Flow Meters and Forced Draft

Of the 14 companies responding, 8 are using steam-flow meters. Four companies give them unqualified endorsement as improving the work of the firemen. One engineer finds the flow meter of value when used in connection with a damper indicator, as it thereby enables the fireman to maintain an adjustment between rate of steaming and admission of air. One engineer finds the flow meter of some little value, but says this would be greatly increased if the meter were provided with a recording attachment which the engineer could inspect at the end of the watch to enable him to correctly gauge the efficiency of a fireman's work. Two other engineers have used the flow meter, but do not find it of any value.

Of the 12 companies responding, 4 use forced-draft equipment. One company uses forced draft on peak of load only; the others use it constantly. The ash pit pressure is limited by the amount necessary to reach a balanced pressure above the grate, which ranges from 1.15 in. with one company to 4 in. with another company. The pressures commonly used are from ½ in. to 2 in. The capacity attained with forced draft is from 200 to 300 per cent of normal rating.

Feed-Water Heaters and Feed-Water Heating

Of 12 companies responding 9 use open heaters and 2 use closed heaters, while one is now changing from closed to open

heaters. In 8 power houses the auxiliaries produce sufficient steam for heating the feed water.

One company supplements its exhaust steam with steam drawn directly from the boilers, and two companies draw steam from the turbine.

Deterioration of Steel Stacks

Of 11 companies using steel stacks 3 have noticed no deterioration. With one of these companies the stacks are lined, with another company unlined, and the third did not say whether the stacks are lined or not. All the other companies report serious corrosion of the steel. They all have unlined stacks except one company, which in lining the stack had left an air space between the brick and the metal, and in this case the corrosion was so serious in a short time that the lining was taken out, the metal scraped, and the lining rebuilt with grouting between the brick and the steel.

All of the unlined stacks reported on are apparently corroding very seriously, and almost entirely on the inside, the corrosion appearing to be worse on the upper rings. This is attributed to the moisture in the flue gases, which is condensed against the cold metal of the stack and, carrying with it a trace of sulphurous acid from the fuel, attacks the metal. As a stack is never scraped or painted on the inside, regardless of the amount of care which may be bestowed upon it on the outside, the corrosion goes on rapidly and uninterrupted, and stacks which are well cared for and frequently painted on the outside, presenting a good external appearance, are in a few years found to be in a dangerous condition, due to internal corrosion.

A simple and effective remedy for this condition is to line the stacks from bottom to top, taking care that the job is thoroughly grouted as it goes up, so that every part of the metal will be protected with cement. Stacks of this construction at the Harrison Street Station of the Commonwealth Edison Co. have been standing for 20 years, much of the time out of service. They have been painted every 2 years and are now apparently in as good condition as when first built.

Trouble with Turbine Blades

Of 13 companies responding 5 have had no trouble with turbine blades or nozzles. Three companies report the breaking

of diaphragm nozzles due to their having been cast in solid with the diaphragm. The trouble was remedied by replacing diaphragms of such construction with those having the blades grouped in detachable segments, which were bolted to the diaphragm.*

Two companies had broken blades caused by insufficient clearance. One company lost blades due to some trouble with the shaft, and one company reported that its blades were clogged with a deposit of mud and scale, which was finally removed with a solution of soda ash, without dismantling the machine.

AIR SUPPLY FOR BOILER HOUSES IN COLD WEATHER

Most boiler houses are not provided with ample passages for the admission of air directly under the grates, but depend upon air being admitted to the boiler room through doors, windows or ventilators. In the summer time these are all open to keep the temperature of the room comfortable for the firemen; for the same reason they are closed during cold weather, although as a general rule in a lighting plant the consumption of fuel and correspondingly the demand for air for the furnaces is greater during cold weather than in warm weather; and if the fires depend upon natural draft for the air supply the closing of all openings into the boiler room has a noticeable effect upon the rate at which the fuel can be burned.

The suction of the chimneys creates a steady demand for air, and when the natural openings to the boiler room are closed this demand can be met only by a difference in pressure between the inside and outside air sufficient to force the required amount of air through such openings as the firemen may overlook or be unable to close. Indeed, it is a universal experience on opening an outside door of a large boiler room in cold weather to encounter an inward rush of air which prompts the visitor to grab his hat to prevent its being blown off.

Tests made during cold weather in three large boiler houses which were provided with special openings for the admission of air and which were not closed at the time of the tests showed a difference in pressure between inside and outside air of 0.07, 0.1, and 0.16 in. of water, respectively. The effect of this loss

*See discussion at end of Report.

of pressure on the fire was, of course, the same as would be caused by partially closing the ash pit doors or partially closing the damper.

If such a difference is found in boiler houses which are provided with what are supposed to be reasonably adequate air passages, which are left open, how much greater must the effect be in boiler houses which have no specially provided openings for the admission of air. To illustrate this, let us assume a boiler room containing twenty 500-hp. boilers, under each of which during the peak of the load 3000 lb. of coal are being burned an hour, or 1000 lb. a minute for the entire plant. Each pound of coal will require say 250 cu. ft. of air. At this rate 250,000 cu. ft. of air per minute, or about 4000 cu. ft. per second, must find its way into the boiler room, and the smaller the area of the openings through which this air is forced to enter the higher will be its velocity, and this high velocity can only be attained at the expense of the draft through the grate and the boiler. In view of this condition, the desirability of ample air passages, admitting air preferably directly under the grate, is apparent.

If in the example given this air were obliged to enter the boiler room through a doorway 7 ft. wide and 7 ft. high its velocity would be 80 ft. per second or 55 miles an hour, which, if encountered in a gale of wind off Cape Hatteras, would be called a hurricane.

Balanced Draft

The principle upon which the system of boiler regulation known as balanced draft is based consists in such regulation of the air supply to a boiler and the exhaust of the gases from the boiler that a substantially uniform or atmospheric pressure is maintained in the furnace for all rates of combustion. This is usually accomplished by causing the steam pressure to automatically control the supply of air to the grate, causing this to increase or decrease according as there is necessity for a change in capacity of the boiler. It is claimed for this system that it increases the capacity and efficiency of both boiler and furnace and permits the use of cheaper fuels.

Other advantages claimed for this apparatus by the manufacturer are increased life of boiler setting and reduction in maintenance and repair expenditures, due to the elimination of

strains caused by unequal expansion and contraction and the disintegration of furnace linings which follows as a consequence. Your Committee has not been able to verify these statements, but believes that the device is worthy of consideration, especially where forced draft is used.

Feed-water Regulators

In the report of the Prime Movers Committee for the year 1912 the following statement appeared under this heading:

"The advent of the flow meter brings to light the fact that the greatest variations in the amount of work which a boiler does are caused by varying the supply of feed water, and to eliminate the fluctuations due to this cause so that the flow-meter indications will refer solely to the manipulation of the fire the feed-water regulator at once suggests itself. An inquiry, however, into the various makes of regulators now on the market shows that their action is intermittent, and the boiler is either taking water in considerable quantities or the feed valve is entirely closed, the result being rapid changes through a wide range in the rate of steaming as shown by the flow meter.

"This condition suggests the desirability of a feed-water system supplied by a centrifugal pump and regulated at each boiler by an automatically controlled valve capable of differential variation according to height of water and rate of steaming."

Your Committee is pleased to state that differential regulation of feed-water supply, referred to in last year's report as being particularly desirable, is now obtainable in regulators of several makes. Great care should be taken, however, in connecting up these regulators, for the reason that when the water connection to the automatic feed-water regulator is connected to the lower part of the steam drum the fluctuations in horse power, as shown on the acompanying curve (Fig. 4), amount to from 300 to 400 hp. The other curve (Fig. 5) shows the results which are obtained after determining and eliminating the cause of this fluctuation. This is accomplished by connecting the water end of the thermostat to the lower part of the main tube header, rather than to the lower part of the steam drum. This tends to eliminate the fluctuations, which are evidently due to the surges taking place at the surface of the water.

With the regulator connected up in this manner there is practically a steady output of steam under constant conditions of firing. The meter is then of great value in assisting the fireman to the most economical boiler operation, any change whatever in

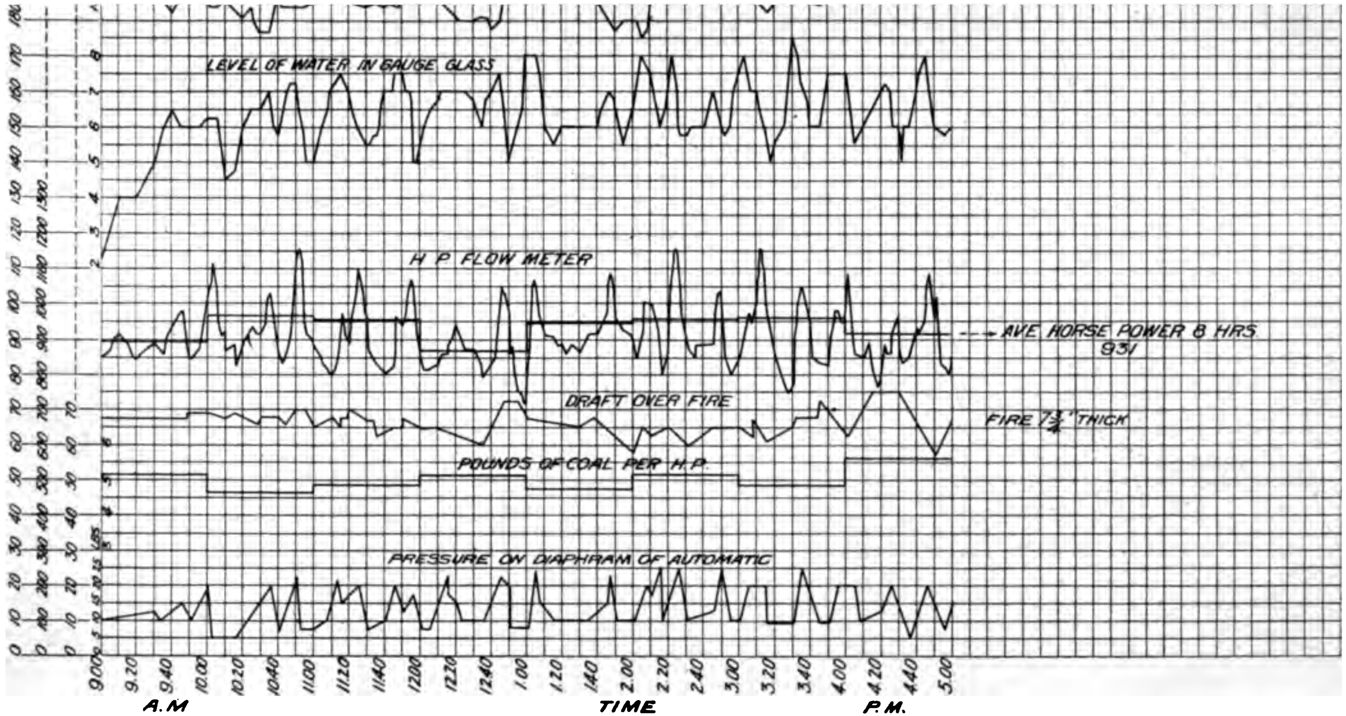

FIG. 4—CURVE NO. 1—TEST NO. 221—CURVE SHOWING FLUCTUATION IN CAPACITY NO. 2 EDGEMOOR BOILERS AS SHOWN BY GEN. ELEC. CO. INDUCTION FLOW METER—BOILER FED BY AUTOMATIC—DATE OCT. 1, 1911

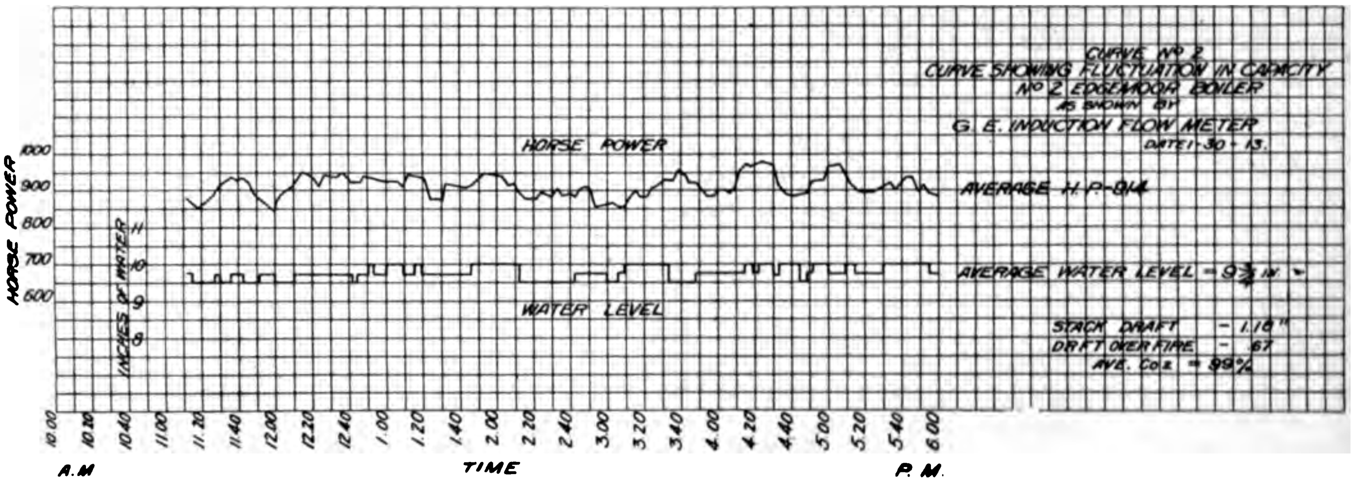

FIG. 5—CURVE NO. 2—CURVE SHOWING FLUCTUATION IN CAPACITY NO. 2 EDGEMOOR BOILERS AS SHOWN BY GEN. ELEC. CO. INDUCTION FLOW METER—DATE JAN. 30, 1913

the condition of the fire under the boiler being immediately indicated upon the dial of the flow meter. The fireman is thus enabled, by careful observation, to maintain his fires in a steady and hence most economical condition.

FLOW METERS FOR MEASURING THE STEAM CONSUMPTION OF TURBINE UNITS

The General Electric Co. TS-2 steam flow meter has proved to be a very satisfactory instrument for indicating steam consumptions on turbine units. The instrument is extremely sensitive and well within the limits of accuracy claimed for it by the makers. It is possible with it to detect faults in the blading of the turbines and other conditions which tend to reduce the efficiency of operation, less than two hours' time being required to obtain this information.

ACCURACY AND VALUE OF CO_2 APPARATUS FOR DETERMINING FLUE GAS COMPOSITION

There are a number of makes of CO_2 recording instruments and indicating instruments on the market which determine with reasonable accuracy the composition of the samples of gas with which they are supplied, but whose value for testing and operating purposes depends largely upon the care and judgment exercised in selecting the gas samples. Few who have not made a study of the conditions realize the great variation in the composition of the different strata of gases in their passage through the boiler, and the indiscriminate sampling of such gases is almost sure to lead to erroneous conclusions.

A graphical illustration of such variation in gas composition is given in Fig. 6, which represents a vertical section through the last pass of a water tube boiler, taken 45 in. in front of the rear water leg. On this section are drawn contour lines, showing in outline the zones occupied by gases containing CO_2 in different proportions. An inspection of this shows that from the third pass of this boiler could be drawn samples of gas, varying all the way from 5 to 14 per cent CO_2. It, is therefore, obvious that any reports based upon analyses of gas samples drawn indiscriminately from such a boiler would be misleading.

One of the precautions to be observed in the installation of CO_2 instruments is in regard to the position at which the gas sample is taken in the flue. The sample should be taken as nearly as possible at the point where the gases leave the heating surfaces, and in all cases near the center of the moving gas currents. Samples taken at other points in the setting will vary all

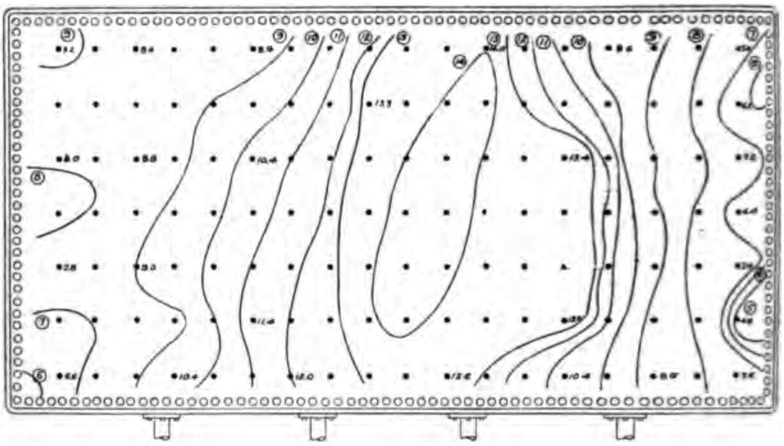

FIG. 6—CHART SHOWING VARIATION IN QUALITY OF FLUE GAS IN 3RD PASS OF 518-HP. BOILER (VERTICAL PASS)
READINGS TAKEN IN PLANE 24 IN. FROM INSIDE OF REAR HEADER
LINES REPRESENT PERCENTAGES OF CARBON DIOXIDE

the way from 4 per cent up, as indicated in the accompanying curves.

Precaution should also be taken for preventing the accumulation of soot and fly ash in the sampling tube. One company reports an arrangement by which the sampling tubes are blown out each day by means of a steam jet.

In answers to questions which have been asked of several large power companies in regard to their experience with CO_2 instruments the following facts have been brought out:

1 Two companies state very definitely that the recording instruments which they use are too delicate and require too much adjusting, cleaning, etc., to make them of especial value to the station engineer.

2 In the case of one company using recorders it has not been possible to make the apparent saving or loss of fuel (as indicated by the recorder and given in its table) agree with the figures obtained on evaporative tests.

3 One company reports that with the use of these instruments they have been able to increase the percentage of CO_2 in their furnaces, but that this increase could not be maintained during any length of time.

4 One large company, using three different types of CO_2 recorders, states that the meters do not assist them in maintaining uniform capacity output.

From the facts which your Committee has been able to assemble it seems safe to say that, assuming the boiler setting to be in perfect condition, a steady output would indicate that the furnace and boiler are working up to their highest efficiency and that any change in the condition of the fire caused by excessive air will be as readily indicated upon the capacity flow meter as upon a CO_2 instrument. In this connection, comparing the value of the CO_2 meter with the capacity meter, it has been the experience of member companies that a boiler can be kept steaming at a more uniform rate with the aid of flow meters than with the aid of CO_2 recorders. It would, therefore, seem that a capacity flow meter can perform essentially all of the functions claimed for the CO_2 meter.

METERS FOR MEASURING FEED WATER

During the year 1912 there has been considerable advance made in the operation of water meters. Possibly the most work has been done upon the v-notch weir method of water measurement.

Properties of V-Notch Weir Method

One of the properties of the v-notch method of measurement which makes it especially valuable lies in the fact that the section of the flow through the v-notch is at all times the same shape, although the area may vary, and this constancy of form tends to simplify the formula and make it accurate. Another property of the v-notch is that its angles may be less than 90 degrees without impairing its efficiency, which enables it to be used for very small quantities of water. These properties

are mentioned by Mr. D. R. Yarnall in a paper published in the Transactions of the A. S. M. E. in October, 1912.

The Venturi Meter

The Venturi meter is highly spoken of by several companies that are using it to measure feed water. The installation of these meters is usually a simple matter, as the meter itself forms part of the feed line, but as accuracy of the indications requires a short length of straight pipe it is not always convenient to find a location for the meter, since the meter itself and the straight piece ahead of it require a straight run of pipe from 15 to 20 diameters in length. The meter is not so perfectly adapted for service with pumps which give an intermittent flow of water, but it is ideally adapted for use with centrifugal pumps, where its indication is found to be accurate within one per cent.

The General Electric Water-flow Meter

The General Electric Co. now has on the market a feed-water meter which operates on the same principle as its steam capacity flow meter. This is of the modified Pitot tube type. In the use of this meter they provide for the installation of a reducing nozzle in the feed line at the point of application of the flow-meter nozzle. This reducing nozzle makes it possible to increase the velocity in the pipe without a loss in pressure in cases where the normal velocity of water in the pipe would be too low to measure the water accurately. These reducers are made of definite diameter and the surface exposed to the flow of water is always of the same degree of roughness, which is not true of commercial piping. For this reason it is not necessary for the customer to measure his pipe diameter, and the results obtained are accurate within 1 per cent, where without the reducer the accuracy may not be better than 2 per cent, due to errors in determining the true pipe diameter and also to the variable roughness of the pipe.

FUEL OIL AND ITS COMBUSTION

Petroleum oil because of its high calorific value and its great adaptability to boiler work is almost the ideal fuel for such purposes.

This fuel, which was formerly supposed to be found in quite restricted localities and in limited quantities, is now known to be

widely distributed, and enormous deposits in new localities are being continually discovered. One of the latest of these to be brought to attention is the oil fields of Mexico, which bid fair to become an important factor in the production of petroleum.

The enormous increase in the demand for petroleum products, principally the lighter oils, has been a factor in the recent production of crude petroleum. This increase has been sufficient to greatly reduce the consumption of petroleum for fuel purposes, but with the increased yield which may be expected from new deposits, and with the increasing price of coal, we may expect that oil fuel will, before long, regain its former position as one of the steam-producing fuels.

Your Committee has been fortunate in receiving a discussion of fuel and its combustion, written by Mr. Arthur D. Pratt, assistant to the advisory engineer of the Babcock & Wilcox Co., which communication appears in full in Appendix E. This paper is an exhaustive description and discussion of the various means and appliances for burning fuel oil, a comparison of its cost with that of coal, and a comparison of the efficiencies of various makes of burners. One statement of interest which might be mentioned is that of steam atomizer burners which have now been so perfected that they will operate on from 1 to 2 per cent of the steam generated by a boiler which they serve. The capacity of a good steam atomizing burner is placed at about 400 boiler hp., and it is possible with such burners to operate a boiler at from 200 to 450 per cent of rating.

The author discusses the use of fuel oil with other fuel as standby and emergency service, and is of the opinion that it is of value for this purpose, although it is not advisable to use it constantly in connection with other fuel.

The paper, which it is said will appear in substantially the same form in the new edition of "Steam," the bulletin of the Babcock & Wilcox Co., is well worth the perusal of any one who is using or contemplates the use of fuel oil.

RILEY STOKER

A new design of stoker has been brought out in the past year which is intended to combine the best features of inclined underfeed and overfeed stokers and shaking grates. The so-called Riley self-dumping stoker is of the inclined underfeed

type; that is, the coal supply is forced up from beneath the point where the air is admitted, and is then worked along toward the bridge wall. It differs from other underfeed stokers in that instead of stationary dead plates it has moving air-supplying grates, carried by the reciprocating sides of the retorts, and also moving overfeed grates, extending across the entire width of the stoker. Beyond these are pushers for continuously dumping the refuse. The travel of these reciprocating parts is adjustable, so as to control completely the movement of the fuel bed and the dumping of refuse.

The manufacturer claims many distinctive features for this stoker, among which are smokelessness, adaptability to varied fuels, arrangement for the self-dumping of refuse, ease with which it cuts away and prevents the formation of clinkers and simplicity of construction. It is claimed that these grates have developed from 200 to 250 per cent boiler rating, with an efficiency of from 73 to 77 per cent. The power required to operate this stoker was 1½ hp., and 20 hp. was used for driving the blower.

As this stoker has only recently been put upon the market your Committee has not been able to verify the claims of the manufacturer, which are substantially embodied in the statement made.

VELOCITIES IN STEAM PIPING

In the discussion of the last year's report the question was raised in regard to steam velocities to be employed in steam-turbine stations. This matter depends so largely upon local conditions that no definite practise may be described; some steam velocities as high as 9000 ft. per min. prevail in modern plants where the arrangement permits.

Each plant must be individually considered, having in mind that there must be a compromise between the pressure losses, radiation losses and investment involved. These principles have been broadly discussed in technical literature.

New Boiler Unit "Myriawatt"

The February number of the N. E. L. A. *Bulletin*, in referring to the new unit for expressing boiler power, reads as follows:

"There has been a good deal of inquiry recently as to the proposed new unit 'myriawatt,' which would seem to be badly

needed in expressing the relations between present electrical units and steam units, or boiler power.

"In an effort to get rid of 'horse power' entirely a paper was recently presented to the American Institute of Electrical Engineers by H. G. Stott and Haylett O'Neill, suggesting that the term 'myriawatt' be used instead. The term is derived from the Greek 'myrias,' meaning ten thousand, and the term 'watt.' One boiler horse power very nearly equals ten kilowatts or 10,000 watts. Hence 'myriawatt.' In terms of British thermal units one kilowatt is equal to 3415 units per hour and one boiler horse power to 33,475 units per hour. A 'myriawatt' would then be 34,150 British thermal units per hour or only two per cent more than the boiler horse power. It is the common practise to rate water tube boilers at one boiler horse power per 10 sq. ft. of heating surface. As this is an arbitrary measure no harm can be done by increasing the unit two per cent, and boilers might hereafter be rated at one 'myriawatt' per 10 sq. ft. of heating surface.

"At a joint meeting of the Standard Committee of the American Institute of Electrical Engineers and a special committee appointed by the American Society of Mechanical Engineers the new term was recommended and Mr. C. O. Mailloux was appointed to present this unit to the International Electro-Technical Commission at Zurich. It seems quite probable that the term will be adopted abroad, where 'boiler horse power' is never used and no suitable substitute exists."

In presenting this suggestion for a new boiler unit attention should be called to the fact that certain English engineers have made decided objections to the proposed unit. Your Committee feels that it might be well to let the National Engineering Societies pass on the question of its adoption.

GAS POWER

In preceding reports of the Committee all important developments, both practical and novel, have been taken up at length. There have been no new developments in this field of engineering this year. The Committee communicated, as formerly, with all of the leading manufacturers of gas-power apparatus, and has been directly informed that no new types of machinery were bought during the past year. In the main they report that minor details of design are being perfected to improve operation.

The market for gas engines and producers has been unusually quiet the last twelve or more months. In your Committee's judgment this may be attributed to the great trend toward centralization of power which invariably calls for units of large

capacity. It is now commonly understood that the heavy-power gas-engine installation cannot be financially economical unless the cost of coal should range considerably above the existing average prices. Due to the relatively large investment and maintenance costs of a gas plant, even smaller sizes have suffered a loss in the prestige accorded them by the industries a few years ago.

OIL ENGINES AND STATISTICS REGARDING THE GENERAL OIL SUPPLY

There has been one item in the nature of a recent rapid rise in the price of oil that requires particular mention. The eastern and central sections of the country have been most affected, while prices in the extreme west and southwestern districts have advanced but slightly. The following tables and statements are an abstract from the United States Geological Survey Bulletin:

Production of Petroleum

REPORTED PRODUCTION OF OIL (BARRELS) IN UNITED STATES AND WORLD

	1909	1910	1911	1912
East of the Rockies	127,224,000	136,547,000	139,315,000	133,200,000
West of the Rockies	54,776,000	73,010,000	81,134,000	87,000,000
Total in United States	182,000,000	209,557,000	220,449,000	220,200,000
Estimated world production	298,346,000	327,474,000	345,512,000	347,000,000
Per cent of United States production to world production	61.1	63.8	63.8	63.4

Petroleum Prices

AVERAGE PRICE PER BARREL

	1908	1909	1910	1911
California	$0.523	$0.564	$0.490	$0.477
Colorado	.913	1.022	1.015	1.005
Illinois	.672	.640	.593	.630
Indiana	.976	.870	.726	.740
Kansas	.414	.389	.394	.476
Kentucky	.971	.811	.693	.696
Louisiana	.605	.661	.522	.529
Michigan / Missouri	1.466	1.362	1.326	1.000
New York	1.786	1.655	1.342	1.311
Ohio	1.306	1.244	1.074	1.075
Oklahoma	.386	.364	.383	.472
Pennsylvania	1.791	1.659	1.354	1.321
Texas	.598	.712	.742	.688
Utah / Wyoming	1.570	1.655	.810	.664
West Virginia	1.776	1.642	1.338	1.303
Total	.723	.704	.610	.608

From reports of the United States Geological Survey, made in January, 1913, the average prices quoted seem to indicate a decided advance, particularly in the central and eastern fields. The advances made during the year 1912 were as follows:

Pennsylvania	70 cents increase
Illinois, Ohio, Indiana	35 cents to 40 cents increase
Texas	10 cents to 20 cents increase
California	5 cents increase

It has been observed that since January 1, 1913, there have been unusual advances in certain fields, the Pennsylvania oils chiefly commanding prices nearly double those of a year ago.

General Petroleum Situation

The January, 1913, Bulletin of the United States Geological Survey states:

"There was no considerable change in the quantity of petroleum produced in the United States in 1912, compared with 1911. Nevertheless, according to David T. Day, of the United States Geological Survey, the year was full of remarkable incidents, as is usual in the history of this article of commerce, which depends for its statistical position more upon the chances of new discoveries and less upon trade demands than any other commodity except gold.

"As a rule, the eastern fields declined in production, because it was impossible to keep up the great output of 1911 without large additional discoveries of new pools in the older fields. The eastern decline was, however, offset by the increase in California, where the San Joaquin Valley fields (Midway, McKittrick, Maricopa, etc.) are still at the height of the gusher stage.

"It will take much time to calculate the amount of oil sold at the different prices of the year, but it is evident that the total value of the product increased markedly, being about $150,000,000 compared with $134,144,752 in 1911.

"STOCKS. In all the fields, except those of California and the Gulf, there was a steady drain on stock during the year, so that from a total of 81,789,390 bbl.—over a half year's output—on January 1, the stock declined to 69,000,000 bbl. at the end of the year. This drain reflects the increased capacity of the refining plants of the United States, the greatly increased exports, and a gradual change in the general condition of the industry by which gasoline has become much more in demand, so that the trade is

well satisfied with heavier grades of gasoline or naphtha. For this reason the dividing line between naphtha and kerosene has necessarily been drawn nearer to kerosene, a large quantity of oil has been distilled into the gasoline portion of the products and a reduced output of kerosene has resulted. On the other hand, the heavy residues which are marketed as fuel oils have come into greater demand, and, owing to the ever-evident effort to increase the yield of light products by splitting up these residues, the supply of fuel oil has not kept up with the demand. The advent of internal-combustion engines, such as those of the Diesel type, promises still higher prices for fuel oils. The United States has been slow in the adoption of these new engines, but their general adoption abroad has pointed the way to rapid increase in their use here.

"PRICES. The general decline in production, except in California, would doubtless have been much greater but for the effort to apply laws of supply and demand by increase in prices. Prices advanced so greatly during the year as to stimulate drilling, even in the old New York and Pennsylvania pools, and so checked the decline in output. Formerly this plan has not been so successful. In the Mid-Continent field also it checked the decline, so that the product will come within 4,000,000 bbl. of the maximum output (in 1910). In the Appalachian field, where higher prices and very cheap methods of pumping oil make the decline slow in any event, the great rise in price from $1.30 to $2.00 a barrel seems to have checked the normal decline and even to have effected an increase, which, though slight, was gratifying.

"DECLINE ABROAD. Another feature tending to strengthen the position of oil in this country is the decrease in production in Russia from 66,183,691 bbl. in 1911 to about 60,000,000 bbl. in 1912. Roumania increased its product slightly, but not sufficiently to offset the Russian decline. The chief decrease was in the Baku oil field. The world's consumption of oil, according to Dr. Day, is now about a million barrels a day, the United States furnishing more than all other countries."

The following statements regarding the oil situation in the United States are taken from "Production of Petroleum in 1911," issued by the United States Geological Survey, and published within the last few months. The general statements regarding the

supply and demand here quoted are based upon the conditions of the trade observed during the latter part of the year 1912.

Fuel Oils

"GENERAL. The most important feature developed by the oil industry of 1911 has been the realization of a supply of fuel oil large enough to be reckoned on as a national factor in power production. During 1910 arguments became convincing that fuel oil was sufficiently plentiful on the Pacific coast to justify great trade and manufacturing expansion in California. Oil has been adopted as fuel on the northern transcontinental railroads for significant portions of their lines. The introduction of oil as fuel as far north as Alaska, without bringing consumption up to the level of present production, has given assurance of a permanency of supply sufficient for the industrial needs of the whole Pacific slope.

"The solution of the corresponding problem on the Atlantic coast received much encouragement in 1911 by the great development of oil supplies in Mexico. The quantity of oil which the Mexican fields are now ready to furnish is variously estimated at from 6,000,000 to 12,000,000 bbl. a month. The total product was perhaps a tenth as much, the production being limited neither by supply nor demand, but by transportation facilities. The needed tank steamers are being furnished as rapidly as they can be built, and meantime the popularity which fuel oil has attained has already led to a doubling of its market price.

"It should be borne in mind, however, that with a line of tank steamers sufficient to carry all the oil that can now be furnished for the eastern coast, the market would probably be temporarily over-supplied. The consumers of fuel require time for the substitution of oil for coal, although the many advantages of the former are obvious.

"In view of the inability of producers to furnish fuel oil in the desired quantity, it is most fortunate that it is no longer necessary to convert oil into power by burning it under boilers. The various internal combustion engines of the Diesel type, in which a great variety of oils can be injected directly into the cylinders, have greatly raised the efficiency of oil for power; but this same revolution in method of burning involves changes in the construction of the engine which will require time for introduction.

Manufactures

"The quantity of oil used as fuel in manufacturing and other industries can not be computed with satisfactory accuracy; but it is estimated that, including railroad use, nearly 50,000,000 bbl. of the California oil went for fuel. In Texas and Louisiana the fuel oil used is estimated at 9,000,000 bbl., much of which was in the form of residues after light distillates were taken off. In the Mid-Continent field, also, crude oil as fuel is fast giving place to these 'topped' oils. Of this material about 2,000,000 bbl. were consumed. Little oil from the eastern fields finds use as fuel, since the heavy residuum is valuable for manufacture into lubricants, paraffin wax, etc. In all probably nearly 62,000,000 bbl. were consumed as fuel in 1911 in the United States; a fair estimate of the consumption for the preceding year is 61,000,000 bbl., the increase showing a growing appreciation of oil as fuel.

"The chief use of gasoline is as internal combustion fuel, and the quantity of this material used will be referred to elsewhere.

United States Navy and Merchant Marine

"The third interesting use of fuel oil is for water navigation. In this the advance in 1911 was world wide.

"Experience with fuel oil in the United States Navy has been so satisfactory that its use will be extended as rapidly as is permitted by considerations of supply and cost. Already the Navy has 19 oil-burning torpedo-boat destroyers, and 8 battleships which burn oil as auxiliary to coal. The battleships "Nevada" and "Oklahoma," now under construction, will burn oil exclusively.

"During the year 1911 the Navy used 15,000,000 gal. of fuel oil, and it is estimated that the consumption for the present year will be 21,000,000 gal. Oiling stations of 700,000-gal. capacity have been established at Bradford, R. I., Norfolk, Va., Charleston, S. C., and Key West, Fla. A station of this size is being constructed at Guantanamo, Cuba. At each of these stations provision has been made for a considerable increase in tankage.

"The only naval oil tanker at present in service is the 'Arethusa,' with a capacity of 1,400,000 gal. Each of the Navy's five most recent colliers, however, has provision for carrying 375,000 gal. of oil, and future fuel vessels built for the Navy will probably be oil tankers rather than colliers.

"In the merchant marine the event of interest was the voyage of the 'Honoluluan' from Baltimore, Md., to Seattle, Wash., carrying a cargo of 7000 tons of coal but propelled by oil. The journey covered 14,000 miles and required a barrel of oil per mile. That is, 7000 tons of coal were moved one mile by one barrel of oil. The oil weighed 1866 short tons, and to serve the same purpose it is estimated that 5600 tons of coal would have been needed.

"HEAVY-OIL ENGINES. The heavy-oil engine of the Diesel type continues to develop and its extensive adoption for marine service within a comparatively few years seems probable. The 12 most recent submarines will have Diesel engines of 300 to 450 hp.; the submarine tender 'Niagara' will have an engine of 900 hp.; and a 150-hp. engine of this type is being installed in a 50-ft. cutter for experimental purposes.

"The application of Diesel engines to tank and other freight vessels, and even to passenger craft, has extended to a point where the expression 'steamer' is no longer strictly correct, and a new term will be required to distinguish between sailing vessels and those propelled by engines.

"The most significant achievement of fuel oil in engine ships was the voyage of the Danish East Asiatic Co.'s Diesel ship 'Selandia,' which crossed from Copenhagen to London in March, 1912, on her maiden voyage to Bangkok, Siam. The 'Selandia' is of 7000 tons and is propelled by two Diesel engines of 1200 hp. each. All auxiliary machinery, such as cargo winches and electric-light plant, are driven by additional Diesel engines. There are, of course, no smoke funnels. The coal bunker room is saved and most of the boiler space, although the space occupied by the engine is slightly greater than the steam engine required. The oil carried is 1000 tons, of which a ton is burned in two hours under full speed. Two larger Diesel ships have been ordered by the same line."

Two useful specifications covering oils for internal combustion engines are given in the Appendix F-1, 2 and 3.

The increased price of oil has temporarily retarded the expected rapid extension of the oil-engine trade in the eastern and central sections of the United States. Some of the builders of the heavy-oil engines listed in the last year's report state that they have not pushed their oil-engine work owing to the rising ten-

dency in the price of crude and fuel oils. Others, however, record their confidence in the present availability of various grades of petroleum and tar oils for oil-engine operation, and are preparing themselves for an anticipated future demand. Among the prominent builders who in the last year announced having added the oil engine to their list of products are the following:

General Electric Co., Erie, Pa.;
Snow Steam Pump Works, Buffalo, N. Y.;
Fulton Iron Works, St. Louis, Mo.;
Covington Machine Co., Covington, Va.;

which are in addition to the builders heretofore active, namely:

Busch Sulzer Bros., Diesel Engine Co., St. Louis, Mo.;
Lyons Atlas Co., Indianapolis, Ind.;
De La Vergne Machine Co., New York, N. Y.

The large stationary engine, using heavy oils, existing heretofore mainly in the vertical type, has recently made its appearance in the horizontal type, the advantages claimed being greater simplicity, accessibility and lesser cost.

Fuel costs abroad, being considerably higher than in this country, have, naturally, excited intense interest in the building of oil engines by leading European manufacturers, and a large number of important modifications have been made. American manufacturers are apparently taking advantage in many instances of European developments. The Sulzer Brothers (Winterthur, Switzerland) type of construction has already been used by a well-known American firm. The designs of the Messers. Tosi, of Legnano, Italy, will be followed by another American engine-building company, and those of Mirrless, Bickerton & Day, of Stockport, England, are to be largely adopted by one of our principal electrical manufacturers. Messers. Carels, of Ghent, have a direct representative in the United States. Professor Junkers of Aachen, Germany, has designed and constructed a noteworthy valveless two-cycle oil engine, possessing an excellent combustion chamber, which gives most satisfactory thermodynamic results. While this engine has barely emerged from the laboratory its practical use is being awaited with keen interest. The inventor of the engine is scheduled to discuss the details of his design before the Gas-Power Section of the Amer-

ican Society of Mechanical Engineers at their Spring meeting in Baltimore, and a description of the engine may be found in "Power," January 23, 1912.

In general, the types above mentioned are described in Chalkley's book on Diesel Engines, reference to which is made in the Appendix H. Some of the American companies have not made arrangements with European builders, but are working out the details of their own engines independently, possibly availing themselves to a large extent of the experience of others.

The oil engine has now assumed a definite part in the production of power in this country. In round numbers there are over 300 installations of medium and heavy-power oil engines here, aggregating about 75,000 hp. It is interesting to note that Phelps, Dodge & Co. (New York) have purchased two 1000-hp. Carels-Diesel engines for their Arizona mining properties, which will be the largest engines installed in this country up to the present time. There have been a number of 400 and 600-hp. engines built here for exportation to Mexico.

An admirable review of the foreign oil-engine situation was presented by H. J. K. Freyn in his address before the American Society of Mechanical Engineers in December, 1912. (See Appendix G.) This paper also dwells upon other gas-power topics, and is, therefore, particularly recommended to those who are interested in this subject.

Two valuable opinions relative to the oil engine, were received from important sources, which proved deserving of being published in full.

LETTER No. 1 (from officer, U. S. Corps of Engineers, Sea Coast Defence)

"I have read much about the Diesel engine and have given it a great deal of study. I have recommended that it be installed in a fortification in Manila Bay, the power plant of which will consist of seven 150-kw. Diesel engine-driven sets.

"I believe the high-pressure oil engine has a great future as a prime mover, especially when used in lighting service. To insure continuous service it might be necessary to have a greater number of reserve sets than is usually considered desirable with steam-driven apparatus. On the other hand, the small Diesel engine is as economical as the large, and, except for the matter of first cost, gives much better operative conditions. On account of the quickness of starting and the fact that the engine will operate at half load almost as economically as at full, the num-

did not provide for a sufficient number of bearings to support the shaft. The new engines provide a bearing between fly-wheel and generator. In case a fly-wheel is used on the other side of the engine this should be an outboard bearing.

"GENERAL DISCUSSION OF ADVANTAGES AND DISADVANTAGES. The principal advantage is, of course, the saving in fuel cost, and other advantages are the short time required to start the engine and the economy in space and handling of fuel. The disadvantages are high maintenance, the necessity of more skilled and experienced operators, lesser reliability than with the steam plant, high investment, and last, but not least, the fact that the user is tied up, almost beyond the possibility of breaking away, to a kind of fuel of which the price seems to be very unstable. I should think that the recent increase in the price of fuel oils would make any one investigate very carefully before adopting this type of engine."

It is to be understood that the engines in the plant described were of the first to be installed in this country, and it is to be expected that the more recent improvements in the various designs mentioned will largely obviate the principal difficulties encountered.

Humphrey Gas-power Pump

In view of the interest attached to the unique gas-power pump developed by Mr. H. A. Humphrey, of Great Britain, and described in last year's report, your Committee has continued to watch the progress that is being made. It believes the present situation to be sufficiently summed up by Mr. Humphrey himself in the following statement obtained through correspondence:

"Steady progress is being made with the Humphrey pumps and quite recently two of the large pumps for the Metropolitan Water Board have been started to work at Chingford and are giving the greatest possible satisfaction. The larger of these pumps was guaranteed to deliver 40,000,000 gal. per day, and is considerably exceeding this output. The fuel consumption was guaranteed at 1.1 lb. of coal per actual water-hp-hr. and the approximate measurements which have been so far possible show that a still lower consumption will be realized, probably below 0.9 lb. The quiet and smooth running of these pumps is remarkable, it being possible to balance a coin on edge on the combustion chamber while the pump is at work. We are not prepared to make any statement regarding the application of a pump for generating electric-motor power, except to say that experiments are being continued in this direction and that thermal efficiencies on the indicated horse power in the gas cylinder up to

30 per cent, calculated on the gas burned, have been realized. As we still have patents pending it is not desirable to say more on this subject."

As supplementary information, the following abstracts from London *Engineering* of January 24 and February 14, 1913, are taken:

"THE HUMPHREY PUMPS AT CHINGFORD. The first of the five large Humphrey pumps which Mr. W. B. Bryan, the engineer of the Metropolitan Water Board, has installed to feed the new Chingford reservoir, was started up last Sunday with the most complete success, there not being the slightest hitch of any nature whatever. The pump, which was rated at 40,000,000 gal. per day, is very considerably exceeding this output, the discharge being fully at the rate of 50,000,000 gal. per day. It works extremely quietly and with very little vibration, it being easy to balance a penny on edge on the top of the combustion chamber with the pump at work. The combustion chamber is 7 ft. in diameter, and the number of cycles 9 per minute.

"The conditions required the set of pumps to have an aggregate capacity of 216,000,000 gal. per day, the lift being 25 to 30 ft.

"The fuel consumption of the Humphrey pump was guaranteed not to exceed 1.1 lb. of anthracite per actual pump-hp-hr., a penalty of $5000 being attached to every 1/10 lb. consumption in excess of this figure. Another clause in the contract imposed a penalty of $100,000 should the plant prove a failure.

"It was a somewhat bold step to accept a contract under such heavy penalties for pumps 7 ft. in diameter, and developing each between 200 and 300 hp., on the basis of an experimental pump with an output equivalent to about 35 hp. only; but the results have undoubtedly thoroughly justified Mr. Humphrey's confidence in the capabilities of his remarkable contribution to the progress of mechanical engineering.

"Owing to the fact that spent gases are exhausted at atmospheric pressure the pumps work practically without noise.

"Provision has been made by which the scavenging air duct can be kept charged with air at a pressure of ¾ lb. to 1¼ lb. per sq. in., a device which endows the pump at need with a considerable overload capacity. Up to the present, however, the Chingford pumps have taken in their scavenging air at atmospheric pressure, and even so the output is so substantially in excess of the requirements of the contract that it is perhaps doubtful whether the need will ever arise for making use of this arrangement for taking overloads.

"The fuel required for operating the pumps is supplied from a Dowson gas plant; this consists of four producers, one of which is rated to convert into gas 138 lb. of anthracite per hr., and the other three, 370 lb. each."

The American manufacturers of the Humphrey pump, the Humphrey Gas Pump Co., of Syracuse, N. Y., have energetically taken up the problem and are constantly carrying on various experiments. They have no definite report to offer at the present time, but state that their numerous tests have resulted very favorably.

The Committee has not been able to directly investigate and verify the success of this interesting apparatus, and is therefore in position to include only such information as it has obtained through the channels mentioned.

GAS TURBINE

The most recent capable account of the present status of the gas turbine was detailed by our esteemed British contemporary, Dugald Clerk, in a paper under this heading delivered at the Dundee meeting (1912) of the British Association for the Advancement of Science. The author stated "that engineers engaged in the development of the internal-combustion engine have long recognized that great advantages would come from substituting rotary for reciprocating movement, and accordingly many attempts have been made to produce a commercial gas turbine. So far, no attempt has succeeded, the practical difficulties having proved too serious. Much useful knowledge, however, has been obtained by able experimenters, and we are now in a position to consider the difficulties afresh, with some experimental data at our disposal."

The author described the three leading gas turbines that have been developed and the results obtained from them. The entire development he reduced to the following conclusions:

"The existing internal-combustion engines are quite satisfactory for small and moderate power units; but the weight increases so rapidly with increase of cylinder diameter that large units, such as 20,000 hp. per shaft, easily attained by the steam turbine, have proved quite impossible for the reciprocating gas engine. To apply internal combusion for the purpose of such large units it appears necessary to dispense with the cylinder piston and crank. I fear that this cannot be done on the lines of either constant pressure or explosion turbines here briefly dis-

cussed. The results obtained appear only to show that progress can hardly be expected on the lines of flame impinging on turbine blades, either in impulse or reaction turbines. Several engineers have suggested the use of explosion to give water velocity, which velocity actuates a water turbine of some form. Mr. Humphrey, in his paper to the Institution of Mechanical Engineers, figures such a combined gas and water turbine; and, although in the form suggested by him the conditions required too cumbrous a machine, yet it does seem that the more hopeful line is to use explosion and expansion to give water velocity, and so avoid all heat difficulties in the turbine part of the apparatus. True, such an arrangement still necessitates a reciprocating mass of water, but it will probably be found that great gain in weight can be obtained by the suppression of the piston, connecting rod, engine frame and crank. This line seems to me to be a much more hopeful one than any scheme involving the direct contact of flame with turbine blades."

THE ILLUMINATING-GAS ENGINE

In 1910 your Committee on Gas Power investigated in particular the use of the illuminating-gas engine. It has been considered desirable after the lapse of three years to again give some attention to this subject. Accordingly, your Committee selected several typical localities and called for information as to the manner in which the illuminating gas is now being generally regarded by the small user of power in the cities.

Broadly speaking, the returns show that the number of engines now in use instead of increasing have fallen off very noticeably. While the reports vary some, there seem to be several contributing factors, the more important of which are the growing demand for motor drive, especially in confined locations, on account of its numerous advantages, such as reduction in the cost of electric power, lower maintenance and less need of attention and supervision.

GENERAL HIGH-PRESSURE TRANSMISSION AND DISTRIBUTION OF POWER GAS

This problem has hitherto frequently attracted the attention of power experts, but this has never proceeded beyond the paper stage in this country. It has been proposed to gasify culm banks at the coal mines and transport the gas by pipe line to the markets, but the excessive investment required to install such a system

makes it at once prohibitive. The proposition, however, has not been without either warm advocates or financial support abroad, and, in fact, has become a matter of realization in the generation and distribution of producer gas in South Staffordshire, England. This plant was first placed in operation in 1905 and supplies an area of 123 square miles. Both the construction and practice of the plant have been the subject of a paper by H. A. Humphrey, Esq., before the Institution of Civil Engineers (Great Britain), abstracts of which appear in the January 17, 1913, issue of the *Electrician* (London).

CONCLUSION

As will be seen from the above report, there has been no striking development during the past year in any of the various forms of prime movers which are applicable to central-station use. At the same time much thought is being given to improving the efficiency and reliability of steam turbines and water wheels, and an earnest effort is being made to develop an internally fired heavy-oil engine. Much attention is being devoted to raising the efficiency of the boiler and the boiler-room in general. Your Committee has also endeavored to cover briefly the European developments. In the Appendices are presented in full a considerable number of letters on various subjects by well-known engineers.

In conclusion, the Committee desires to acknowledge and to express sincere appreciation of the valuable assistance received from the large number of manufacturers, operating companies and engineers who have contributed to this report.

Respectfully submitted,

Committee
- I. E. MOULTROP, *Chairman*
- W. L. ABBOTT
- E. D. DREYFUS
- J. B. KLUMPP
- JOHN HUNTER
- J. F. VAUGHAN
- P. M. DOWNING
- W. N. RYERSON
- H. L. COBURN
- P. T. HANSCOM
- O. B. COLDWELL
- D. W. MEAD

APPENDIX A

THE KINGSBURY THRUST BEARING

BY W. W. SMITH, LIEUT., U. S. NAVY

(*Extract from Journal of American Society of Naval Engineers, Vol. XXIV, No. 4, November, 1912*)

(See Report on Turbines, Hydro-Electric Sessions, pages 100 to 130, inclusive.)

APPENDIX B-1

WATER-WHEEL RUNNERS AND RUNNER MATERAL

BY ALLIS-CHALMERS COMPANY

(See Report on Turbines, Hydro-Electric Sessions, pages 100 to 130, inclusive.)

APPENDIX B-2

IN REGARD TO WATER-WHEEL RUNNERS AND RUNNER MATERIAL

(*Letter from I. P. Morris Company*)

(See Report on Turbines, Hydro-Electric Sessions, pages 100 to 130, inclusive.)

APPENDIX B-3

WATER-WHEEL RUNNERS AND RUNNER MATERIAL

(*Letter from Viele, Blackwell & Buck*)

(See Report on Turbines, Hydro-Electric Sessions, pages 100 to 130, inclusive.)

APPENDIX B-4

IN REGARD TO WATER-WHEEL RUNNERS AND RUNNER MATERIAL

(*Letter from Wellman-Seaver-Morgan Co.*)

(See Report on Turbines, Hydro-Electric Sessions, pages 100 to 130, inclusive.)

APPENDIX B-5

IN REGARD TO WATER-WHEEL RUNNERS AND RUNNER MATERIAL

(Letter from the Ontario Power Co., of Niagara Falls)

(See Report on Turbines, Hydro-Electric Sessions, pages 100 to 130, inclusive.)

APPENDIX C

EFFICIENCY TESTS OF WATER-WHEELS AFTER INSTALLATION

BY PROFESSOR C. M. ALLEN, WORCESTER POLYTECHNIC INSTITUTE

(See Report on Turbines, Hydro-Electric Sessions, pages 100 to 130, inclusive.)

APPENDIX D

JOHNSON TYPE PENSTOCK VALVE

(Letter from the Wellman-Seaver Morgan Co.)

(See Report on Turbines, Hydro-Electric Sessions, pages 100 to 130, inclusive.)

APPENDIX E

OIL FUEL AND ITS COMBUSTION

BY ARTHUR D. PRATT, OF THE BABCOCK & WILCOX CO.

Petroleum is practically the only liquid fuel sufficiently abundant and cheap to be used for the generation of steam. The oils found in the United States are those yielding upon distillation one (1) paraffin and two (2) asphalt. To the first group belong the oils of the Appalachian Range and the middle west. These are of a dark brown color with a greenish tinge. Such a variety of valuable light oil is obtained from the distillation of this group that its use as fuel is prohibitive because of price. To the second group belong the oils of Texas and California. These vary in color from a reddish brown to a jet black and are used very largely for fuel purposes.

There has recently been introduced into the oil market a petroleum from Mexico which also has an asphalt base. This is a heavy viscous black oil, and while it has as yet been but little used it may in the future become an important factor in this field.

Fig. No. 10 gives the composition and calorific value of various oils from different sources.

The light and easily ignited constituents of petroleum, such as naphtha, gasoline and kerosene, are oftentimes driven off by a partial distillation, these products being of greater value for other purposes than for use as fuel. This partial distillation does not decrease the value of petroleum as a fuel; in fact, the residuum known in the trade as "fuel oil" has a slightly higher calorific value than petroleum and because of its higher flash point it may be more safely handled. Statements made with reference to petroleum apply as well to this fuel oil.

Many of the oils contain a large percentage of water and silt, which is ordinarily separated by gravity before using, this action being accelerated by heating. Such a separation may be taken care of in most instances by providing sufficient storage capacity for the fuel.

The flash point of petroleum is the temperature at which inflammable gases are given off. Information on the definite flash points of various fuels is unfortunately meager, but it is nevertheless a question of importance in determining the availability of an oil for use as fuel. In general, it may be stated that the light oils have a low and the heavy oils a high flash point. A division is sometimes made at oils having a specific gravity of 0.85, the flash point of oils heavier than this being above 60 degrees fahr., while those lighter have a flash point below 60 degrees fahr. The difficulty of handling oils with safety will naturally increase as the flash point is lowered, but there is no justification for the careless handling of this fuel even when the flash point is known to be high. When proper precautions are taken, in general, the use of oil as fuel is very nearly as safe as the use of coal.

Oils are frequently classified according to their gravity as indicated on the Beaumé hydrometer scale, but such classification can be considered in no way an indication of their relative calorific value.

Comparison of Oil and Coal

Briefly summarized, the advantages of oil fuel over coal may be stated as follows:

TABLE OF COMPOSITION AND CALORIFIC VALUE OF VARIOUS OILS

KIND OF OIL	CARBON	% HYDROGEN	% SULPHUR	% OXYGEN	SPECIFIC GRAVITY	FLASH POINT	% MOISTURE	B.T.U. PER POUND	AUTHORITY
CALIFORNIA COALING					.927	134°		19117	B & W Co
" BAKERSFIELD					.975			17600	WADE
" "			1.30		.992			18257	"
" KERN RIVER					.950	140°		18845	B & W. CO
" LOS ANGELES			2.56					18328	"
" " "					.957	196°		18855	"
" " "					.977		40	18280	"
" MONTE CHRISTO					.966	205°		18878	"
" WHITTIER			.98		.944		1.06	18507	WADE
" "			72		.936		1.06	18240	"
"	85.04	11.52	2.45	.99*			140	17871	B & W. CO
"	81.52	11.01	.55	6.92*		230°		18667	U.S. LIQUID FUEL B'D
"			.87				95	18533	BLASDALE
"					.891	257°		18655	B & W. CO
"			2.45		.973		1.50†	17976	O'NEILL
"			2.46		.975		1.32	18104	SHEPHERD
TEXAS BEAUMONT	84.6	10.9	1.63	2.87	.924	180°		19060	U.S.N. LIQUID FUEL BD
" "	83.3	12.4	.50	3.83	.926	216°		19481	" " " "
" "	85.0	12.3	1.75	.92*				19060	DENTON
" "	86.1	12.3	1.60		.942			20152	SPARKES
" "					.903	222°		19349	B & W. CO
" SABINE					.937	143°		18662	"
"	87.15	12.33	0.32		.908	370°		19338	U. S. N
"	87.29	12.32	0.43		.910	375°		19659	"
OHIO	83.4	14.7	0.6	1.3				19580	
PENNSYLVANIA	84.9	13.7		1.4	.886			19210	BOOTH
WEST VIRGINIA	84.3	14.1		1.6	.841			21240	
MEXICO					.921	162°		18840	B & W CO
RUSSIA BAKU	86.7	12.9			.884			20691	BOOTH
" NOVOROSSICK	84.9	11.6		3.46				19452	"
" CAUCASUS	86.6	12.3		1.10	.938			20138	
JAVA	87.1	12.0		.9	.923			21163	
AUSTR GALICIA	82.2	12.1	5.7		.870			18416	
ITALY PARMA	84.0	13.4	1.8		.786				
BORNEO	85.7	11.0		3.31				19240	ORDE

INCLUDES N
• SILT

FIG. 10—TABLE OF COMPOSITION AND CALORIFIC VALUE OF VARIOUS OILS

(1) Oil being fed by mechanical means, the cost of handling is lower than the cost of handling coal.

(2) Higher efficiencies and capacities are obtainable with oil than with coal. The factors leading to this increased economy

and capacity are the fact that the combustion is more perfect and may be secured with excess air reduced to a minimum; the furnace temperature may be kept practically constant, and there is no necessity for working or cleaning the fires; smoke may be eliminated with the consequent increase in cleanliness of heating surfaces.

(3) The intensity of the fire can be almost instantaneously regulated to meet load fluctuations.

(4) For equal heat value oil occupies very much less space than does coal and the storage space may be located at some distance from the boiler room without detriment.

(5) There is no loss in calorific value where oil is stored, nor danger from difficulties arising from disintegration such as follow if coal is stored in quantity.

(6) Cleanliness and freedom from dust and ashes in the boiler room lead to a saving in wear and tear on machinery.

The disadvantages of oil are:

(1) The requirement that the oil shall have a reasonably high flash point to minimize the danger of explosion and fire.

(2) City or town ordinances may impose conditions relative to oil storage; that is, the location and isolation of storage tanks may make its use as fuel out of the question.

(3) The necessity that the boilers and furnaces be especially adapted to the use of this fuel. When this feature is neglected the upkeep cost of both boiler and setting will be higher than with coal fuel. Such an objection can be entirely overcome, provided the installation be entrusted to those experienced in the field and the operation of the plant be placed in the hands of intelligent labor.

Many tables have been published with a view to comparing oil with coal. Such of these as have their basis on the relative calorific values of oil and coal are of only limited value in view of the higher efficiencies obtainable with oil. Fig. 11 takes into consideration this variation in efficiency, but is based on a constant calorific value for the oil. This and tables of a similar character, while useful as a rough guide, can be considered only as a most approximate basis for accurate comparison. The features entering into such comparison, namely, the space available for fuel storage, the facilities for conveying oil by pipe lines, the hours of plant operation, the load factor, coal required for bank-

ing periods, etc., etc., are often much more important than the relative cost of the two fuels in determining the advisability of an oil installation.

Burning of Oil Fuel

The requirements for the successful burning of oil fuel, together with the factors necessary for the meeting of such requirements, may be summarized as follows:

(1) Its atomization must be thorough, which requirement is met by the use of a properly designed burner.

(2) When atomized, the oil must be brought into contact with air sufficient for its combustion, and this quantity must be, at the same time, a minimum to obviate losses in stack gases. Such a requirement is fulfilled by the introduction of air into the furnace either through a checker-work beneath the burners or through openings around them so arranged that a proper distribution is secured. Provision is also necessary for the proper controlling of the quantity of air admitted because of variation in furnace conditions.

(3) The mixture must be burned in a furnace where refractory material radiates heat to assist in the combustion, and the furnace material must be such as will stand up under the high temperatures developed.

(4) The combustion must be complete before the gases come in contact with the heating surfaces, otherwise the flame will be extinguished, possibly to ignite later in the flue connection or stack. This requirement is fulfilled by the providing of ample combustion space and a gas travel of sufficient length to insure that the combustion is completed before the gases strike the heating surfaces.

(5) There must be no localization of heat on certain portions of the heating surfaces or difficulties will arise from overheating and blistering. This feature must be particularly watched where the feed water available is not of the best. This requirement is met by the installation of a suitable burner in connection with the properly designed furnace. The burners must be such that the flames will not impinge directly on the heating surfaces and must be so located that such action cannot take place. If such burners, properly located, are not used, in addition to danger of localizing the heat, with disastrous results, there will

be a decided loss in efficiency due to the cooling of the gases before combustion is completed.

TABLE OF RELATIVE VALUE OF COAL AND OIL FUEL										
GROSS BOILER EFFICIENCY WITH OIL FUEL	NET BOILER EFFICIENCY * WITH OIL FUEL	NET EVAPORATION FROM AND AT 212 °F PER POUND OF COAL	WATER EVAPORATED FROM AND AT 212 °F PER LB OF COAL							
			5	6	7	8	9	10	11	12
			POUNDS OF OIL EQUAL TO ONE POUND OF COAL							
73	71	13.54	.3693	.4431	.5170	.5909	.6647	.7386	.8124	.8863
74	72	13.73	.3642	.4370	.5099	.5827	.6556	.7283	.8011	.8740
75	73	13.92	.3592	4310	.5029	.5747	.6466	.7184	.7903	.8621
76	74	14.11	.3544	.4253	.4961	.5670	.6378	.7087	.7796	.8505
77	75	14.30	.3497	.4196	.4895	.5594	.6294	.6993	.7692	.8392
78	76	14.49	.3451	.4141	.4831	.5521	.6211	.6901	.7591	.8281
79	77	14 68	.3406	.4087	.4768	.5450	.6131	.6812	.7493	.8174
80	78	14.87	.3363	.4035	.4708	.5380	.6053	.6725	.7398	.8070
81	79	15 06	.3320	.3984	.4648	.5312	.5976	.6640	.7304	.7968
82	80	15.25	.3279	.3934	.4590	.5246	.5902	.6557	.7213	.7869
83	81	15.44	.3238	.3886	.4534	.5181	.5829	.6447	.7125	.7772
		NET EVAPORATION FROM & AT 212 °F PER BBL OF OIL.	BARRELS OF OIL EQUAL TO ONE TON OF COAL							
73	71	4549	2 198	2.638	3.077	3.516	3955	4.395	4.835	5. 275
74	72	4613	2.168	2.601	3.035	3.468	3.902	4.335	4.769	5.202
75	73	4677	2.138	2.565	2993	3.420	3.848	4.275	4. 703	5.131
76	74	4741	2.110	2.532	2.954	3.376	3. 798	4.220	4. 642	5.063
77	75	4807	2.082	2.498	2.914	3.330	3.746	4.162	4.578	4.994
78	76	4869	2.054	2.465	2.876	3.286	3.697	4 108	4.518	4.929
79	77	4932	2.027	2.433	2.838	3.243	3.649	4 054	4 460	4.865
80	78	4996	2.002	2.402	2.802	3.202	3.602	4.003	4.403	4.803
81	79	5060	1.976	2.371	2.767	3.162	3.557	3.952	4 348	4.743
82	80	5124	1.952	2.342	2.732	3 122	3.513	3.903	4.293	4.683
83	81	5187	1.927	2.313	2699	3.085	3.470	3.856	4 241	4.627

* NET EFFICIENCY = GROSS EFFICIENCY LESS 2% FOR STEAM USED IN ATOMIZING OIL
HEAT VALUE OF OIL = 18500 B.T U
ONE TON OF COAL WEIGHS 2000 POUNDS
ONE BARREL OF OIL WEIGHS 336 POUNDS
ONE GALLON OF OIL WEIGHS 8 POUNDS

FIG. 11—TABLE OF RELATIVE VALUE OF COAL AND OIL FUEL

Oil Burners

The function of an oil burner is to atomize or vaporize the fuel in order that it may be burned in some such manner as a gas. There are hundreds of burners on the market, but they may

all be classified in three general groups: First, spray burners, in which the oil is atomized by steam or by compressed air; second, vapor burners, in which the oil is converted into a vapor and passed into the furnace; third, mechanical atomizing burners, in which the oil is atomized by purely mechanical means.

Vapor burners have never been in general use and will not be considered. Spray burners are the most universally used and the simplicity of the steam atomizer and the economy of the better types, together with the low oil pressures and temperatures required, make this class a favorite for stationary work, while the loss of fresh water is not a vital consideration. In marine practise, or in any plant where it is advisable or necessary to save feed that would otherwise have to be added in the form of "make-up," either compressed air or mechanical means are used for atomization. While air atomizers are in successful operation in many plants, their use is not general. The air burners require blowers, compressors, or other apparatus occupying space that might be otherwise utilized and require attention not needed when steam is used as the atomizing agent.

Steam spray burners of the early types were at a disadvantage in that their design was such as to cause a tendency for the nozzle to clog with sludge or coke formed by the heat from the oil, without provision for cleaning. In the modern designs, this difficulty has been very largely overcome. Steam atomizing burners, as now found, may be divided into inside and outside mixers. In the former, the steam and oil come into contact within the burner and the mixture is atomized by passing it through the burner nozzle. In the latter class, the steam flows through a narrow slot or a row of small holes in the burner nozzle; the oil flows through a similar slot or hole and is picked up by the steam and atomized. Successful burners of this class are so constructed that the portions forming the orifice may be replaced in case of wear or if it be desired to change the form of the flame. Most of the steam atomized burners used to-day are of the outside mixing class. These burners may be further divided into what are known as flat flame or round flame burners.

When burners of the spray type are used, heating the oil is of advantage not only in assisting in the atomization but also in aiding economical combustion. The temperature to which the oil may be heated is, of course, limited by the flash point of

the oil used, but within this limit there is no danger of decomposition or deposit on the supply pipes. Such heating should be done close to the boiler to avoid excessive radiation losses. If the temperature is raised to a point where an appreciable vaporization occurs, the oil will flow irregularly from the burner and cause the flame to sputter.

In both steam and air atomizing burners, a by-pass should be installed between the oil and steam pipes to provide for the blowing out of the oil-duct. Strainers should be provided for removing sludge from the fuel, and should be so located as to allow for rapid cleaning and replacing without interference with the operation of the burner.

Oil burners in which the means of atomization is purely mechanical have been in use for some time in European countries, but their introduction into the United States has been but a recent occurrence, and their use has been largely limited to marine practise. Burners of this design, like the steam spray burners, are of the flat flame and round flame classes. The round flame type here, however, has given the best results, the satisfactory action of the flat flame mechanical burners having been limited as yet to cases in which it is necessary to burn small quantities of oil only through each individual burner. This system of oil burning is especially adapted to marine practise, as the quantity of steam required to put the oil under pressure is small and may be returned to the system. Furthermore, this method has shown the most satisfactory results where a forced blast is used and the marine practise of a stoke-hole pressure lends itself readily to such a requirement.

The only method by which successful mechanical atomization has been accomplished is by giving the oil a whirling motion within the burner tip. This is done either by forcing the oil through a passage of helical form or by delivering it tangentially to a circular chamber from which there is a central outlet. The oil is fed to these burners under a pressure which will vary with the make of the burner and the rates at which individual burners are using oil. The oil particles fly off from such a burner radially in the form of a cone rather than in the form of a spiral spray, as might be supposed.

With burners of the mechanical atomizing design the method of introducing air for combustion and the velocity of this air are

of the greatest importance in securing good combustion and its effects on the character and shape of the flame. Such burners are located at the front of the furnace and various methods have been tried for introducing the air for combustion. Whereas in the spray burners air is ordinarily admitted through a checker-work under the burner proper, with the mechanical burner it is almost universally admitted around the burner. Early experiments with these air distributers were confined largely to single or duplicate cones used with the idea of directing the air to the axis of the burner. A highly successful method of such air introduction, developed by Messrs. Peabody and Irish, of the Babcock & Wilcox Co., is by means of what they term an "impeller plate." This consists of a circular metal disk, with an opening at the center for the oil burner and with radial metal strips from the center to the periphery turned at an angle, which, in the later designs, may be altered to give the air supply demanded by the rate of combustion. The air so admitted does not necessarily require a whirling motion, but experiments show that where the air is brought into contact with the oiled sprays with the right "twist" better combustion is secured and lower air pressure with less refinement in the adjustment of individual burners is required.

Mechanical burners have a distinct advantage over those in which steam is used as the atomizing agent in that they lend themselves more readily to adjustment under wider variations of load. As will be noted later under "Capacity of Burners," for a given horse power there will ordinarily be installed a much greater number of mechanical than steam atomizing burners. This in itself is a means to better regulation, for, if one of a number of steam atomizing burners is shut off, there is a marked decrease in efficiency. This is due to the fact that when air is admitted under the burner it is ordinarily passing through the checker-work, regardless of whether it is being utilized for combustion or not. With a mechanical burner, on the other hand, when individual burners are shut off, air that would be admitted for such a burner, were it in operation, may also be shut off and there will be no undue loss from excess air.

Further adjustment to meet load conditions is possible by a change in the oil pressure acting on all burners at once. A good burner will atomize moderately heavy oil with an oil pres-

sure as low as 30 lb., and from that point up to 200 lb. or above. The heating of the oil also has an effect on the capacity of individual burners, and in this way a third method of adjustment is given. Under working conditions, the oil pressure remaining constant, the capacity of each burner will decrease as the temperature of the oil is increased, although at low temperature the reverse is the case. Some experiments with a Texas crude oil having a flash point of 210 degrees showed that the capacity of a mechanical atomizing burner of the Peabody type increased from 80 deg. to 110 deg. fahr., from which point it fell off rapidly to 140 deg., and then, more slowly, to the flash point.

These various methods, together with the regulation possible through manipulation of the boiler dampers, indicate the wide range of load conditions that may be handled with an installation of this class of burners.

As has already been stated, results with mechanical atomizing burners that may be considered very successful have been limited almost entirely to cases where forced blast of some description has been used, the high velocity of the entering air being of material assistance in securing the proper mixture of air with the oil spray. Much has been done and is being done in the way of experiment with this class of apparatus toward developing a successful mechanical atomizing burner for use with natural draft, and there appears to be no reason why such experiments should not eventually produce satisfactory results.

Steam Consumption of Burners

The Bureau of Steam Engineering, U. S. Navy, made in 1901 an exhaustive series of tests of various oil burners that may be considered as representing, in so far as the performance of the burners themselves is concerned, the practice of that time. These tests showed that a burner utilizing air as atomizing agent, required for compressing the air from 1.06 to 7.45 per cent of the total steam generated, the average being 3.18 per cent. Four tests of the steam atomizing burners showed a consumption of from 3.98 to 5.77 per cent of the total steam, the average being 4.8 per cent.

Improvement in burner design has largely reduced the steam consumption, although to a greater degree in steam than in air

atomizing burners. Recent experiments show that a good steam atomizing burner will require approximately 2 per cent of the total steam generated by the boiler, operated at or about its rated capacity. This figure will decrease as the capacity is increased and is so low as to be practically negligible, except in cases where the question of feed water is all important. There are no figures available as to the actual steam consumption of mechanical atomizing burners, but apparently they require approximately 0.25 per cent of the total steam. This requirement, however, is to be understood as entirely apart from the steam consumption of the apparatus producing the forced blast.

Capacity of Burners

A good steam atomizing burner properly located in a well-designed oil furnace has a capacity of somewhat over 400 hp. This question of capacity of individual burners is largely one of the proper relation between the number of burners used and the furnace volume. In some recent tests with a Babcock & Wilcox boiler of 640 rated horse power, equipped with three burners, approximately 1350 hp. were developed with an available draft of 0.55 in. at the damper, or 450 hp. per burner. Four burners were also tried in the same furnace, but the total steam generated did not exceed 1350 hp., or, in this instance, 338 hp. per burner.

From the nature of mechanical atomizing burners, individual burners have not as large a capacity as the steam atomizing class. In some tests on a Babcock & Wilcox marine boiler equipped with mechanical atomizing burners, the maximum horse power developed per burner was approximately 105. Here again the burner capacity is largely one of proper relation between furnace volume and number of burners.

Furnace Design

In the burning of oil fuel it is the furnace design upon which the greatest importance is to be placed. Provided a good type of burner is adopted, the furnace arrangement and the method of introducing air for combustion are the all-important factors entering into the results that may be expected. No matter what the type of burner, satisfactory results cannot be secured from a furnace not suited for this class of fuel.

Experiment has shown that the best results are to be expected where ample combustion space is provided and where the oil is introduced into the furnace in the direction in which it increases in height. Such an increase in furnace volume in the direction of the flame insures free expansion and a thorough mixture of the oil with the air, with the consequent complete combustion of the gases before the heating surfaces are encountered. In such a furnace where steam atomization is used, a flat flame burner will give by far the better results. A round flame steam atomizing burner has a tendency toward a long conical flame with which there is danger of impinging on the heating surfaces. Owing to the complete atomization and the lower velocity of projection secured with the round flame mechanical atomizing burner, there is no particular danger from such a cause, and this class readily lends itself for installation in a furnace of such form. The methods of admitting air for combustion in the furnace have already been covered. The burners must be so located that the flames from individual burners do not interfere with each other and do not strike on the side furnace walls. Such an arrangement of burners is necessary to insure an even distribution of heat over the full width of the furnace. In stationary boilers, the best results up to the present time have been secured with steam atomizing burners placed at the rear of the furnace, projecting the flame toward the boiler front. When so located, the burners are operated from the front of the boiler, where peepholes should be provided through which the operator may watch the flame while regulating the burner. The checker-work or fire brick under the burners, through which air for combustion is admitted, must be so arranged as to secure the proper economical results.

With steam atomizing burners introduced through the front of the boiler in stationary practise, it is usually in the direction in which the furnace decreases in height, and it is with this arrangement that difficulties through the loss of tubes may be expected. With such an arrangement, the flame may impinge directly upon the tube surfaces and tube troubles from this source may arise, particularly where the feed has a tendency toward rapid scale formation. Such difficulties may be the result of a blow-pipe action on the part of the burner, the overheating of the tube, due to oil or scale within, or to the actual

erosion of the metal by particles of oil improperly atomized. Such action need not be anticipated, provided the oil is burned with a short flame. The flames from mechanical atomizing burners have a less velocity of projection than those from steam atomizing burners, and if introduced into the higher end of the furnace, should not lead to tube difficulties, provided they are properly located and operated. This class of burner will also give the most satisfactory results if introduced in the direction of increase of furnace volume. This is perhaps best exemplified by the very good results secured with mechanical atomizing burners and Babcock & Wilcox marine boilers, in which, due to the fact that the boilers are fired from the low end, burners introduced through the front are in such direction.

Air Supply

From the nature of this fuel and the methods of its burning the quantity of air for combustion may be minimized. In a test with California crude oil, where the highest authentic efficiency with this fuel was obtained, the ratio of air supplied to that theoretically required was but 1.18 to 1. A slight variation in air supply with oil fuel, however, will affect furnace conditions to a much greater extent than the same variation when coal is used, and for this reason it is essential that flue gas analyses be made frequently. With the air for combustion properly regulated by adjustment of check-work or whatever device is used for its admission, and for the boiler damper properly set, a flue gas analysis should show for good furnace conditions between 13 and 14 per cent of CO_2, with either no CO or but a trace. It is oftentimes difficult, in the operation of a plant, to regulate the steam supply to the burners and the damper position to meet constant variation in load. A device has been patented which automatically regulates, by means of the boiler pressure, the pressure of the steam to the burners, the oil to the burners and the position of the boiler damper. Such a device has been shown to give good results in plant operation where hand regulation is difficult at best, and in many instances is unfortunately not even attempted.

Efficiencies and Capacities with Oil Fuel

Reference has already been made to the highest authentic efficiency secured in the burning of oil. This was secured during

a series of tests made by Dr. D. S. Jacobus at the Redondo Plant of the Pacific Light & Power Co., and was slightly in excess of 83 per cent gross. This efficiency, while never exceeded, has been frequently approached in oil-fired plants.

In some recent tests on stationary boilers where the capacity was limited entirely by the draft available, there was no difficulty in securing 200 per cent of the boiler rated capacity with but 0.5 in. draft at the boiler damper. The question of capacity is largely one of furnace volume, and with mechanical atomizing burners which have a smaller capacity per burner than the steam atomizer, and in this way utilize the furnace volume to the best advantage, an evaporation per square foot of heating surface in Babcock & Wilcox marine boilers has been secured corresponding to over 450 per cent of rating on the customary stationary rated capacity of a boiler, or over 15.5 lb. of water from and at 212 deg. per hr. per sq. ft. of heating surface.

With steam atomizers the capacity is limited by the arrangement for introducing air into the furnace. Such an arrangement has to be adjusted to give high efficiencies at reasonable or expected overloads, and for this reason will not admit sufficient air to give an overload corresponding to that just quoted. With ¾-in. draft at the damper there should be no difficulty in obtaining 250 per cent of a boiler's rated capacity with steam atomizer burners and a good efficiency at lower loads. It is interesting to note that the efficiency at the 450 per cent of rating just mentioned was 69.3 per cent.

Burning Oil in Connection with Other Fuel

Considerable attention has recently been given to the burning of oil as an auxiliary fuel. Experience has shown that the best results are not to be expected where an attempt is made to burn two fuels in one furnace, as complete combustion of the volatile hydrocarbons becomes more difficult, and one fuel interferes with the other. An oil spray injected over a coal fire is undoubtedly a means of increasing the capacity of the boiler, but as it is accompanied by enormous loss in efficiency, is not to be recommended. When burned in separate furnaces, however, under opposite ends of a boiler, the most satisfactory results, both as to capacity and economy, have been secured by a combination of oil and coal and oil and wood. These combination

furnaces have been used most largely in stand-by plants or in plants where the regular supply of fuel is liable to interruption.

Stacks for Oil Fuel

A word as to stack sizes for this class of fuel may not be out of place. With oil, it has been pointed out that the excess air is at a minimum. This, resulting in a decrease in volume of gas for a given boiler capacity, decreases the frictional loss of the gases through the boiler and stack. Such a decrease in frictional loss is partly offset by the loss in head of the gases due to the decrease in exit temperatures that will be found. The draft loss through the fuel bed will, to a large extent, be eliminated, the loss at this point being limited to the frictional resistance offered to the air by the checker-work. These factors, affecting as they do the intensity of the draft, bear directly on the height of stack to be used. The smaller volume of the gases reduces the cross-sectional stack area necessary. It is generally assumed that this area will vary directly as the volume of gas to be handled with oil. The volume of gas will be approximately 60 per cent of the same volume were coal to be used, and stacks for oil fuel should, therefore, have approximately 60 per cent of the cross-sectional area of stacks for coal-fired boilers of a given capacity.

In determining the height of the stack to be furnished there are two aspects from which the subject must be considered. It is essential, with the high temperatures found in a furnace using this fuel, that a draft suction be maintained throughout the boiler setting under any and all load conditions. This is necessary simply from the viewpoint of protecting the boiler brickwork. On the other hand, if more draft is supplied than is needed for the best economical results, there is a tendency on the part of operators toward maintaining a constant gas flow through the boiler, regardless of the rate at which it is being operated. This naturally leads to an excess of air at light loads.

It is evident, therefore, that the stack height should be such as will give ample draft with the boilers operating at the maximum load they will be called upon to carry, but with this maximum draft requirement determined, a stack such as will give more than this amount will tend toward a decrease in efficiency at lower loads. This question of variation of draft with

fluctuating loads is best handled by means of some such automatic device as has already been described.

In closing, it may be of interest to give the results of some recent experiments in getting up steam from a cold boiler with oil fuel. A 640-hp. Babcock & Wilcox boiler was used in these experiments. The temperature of the water in the drum in the first test was 93 deg. Steam was raised and the boiler cut into the line in 28 min. after the oil fires were lit. Three minutes after the boiler was cut in, a steam flow meter showed it to be operating at 180 per cent of its rated capacity. In a second test of the same nature, from a temperature of water in the drum of 170 deg., steam was raised and the boiler cut into the line in 23 min., the steam meter indicating that it was developing 23 per cent of its rated capacity five minutes after being cut in.

APPENDIX F-1

SPECIFICATIONS FOR INTERNAL-COMBUSTION ENGINE FUELS

BY IRVING C. ALLEN

(Abstracted from paper read at the December, 1912, meeting of the A. S. M. E.)

The consensus of opinion seems to be that an oil to burn with success in heavy-oil engines should possess the following characteristics:

(a) SOLIDIFYING POINT. The oil should be fluid at 0 deg. cent. If it be heavy or viscous or contain a considerable portion of asphaltum or paraffin, it will become sluggish and stiff at low temperatures, and it will be necessary to use considerable heat to warm it before it can be run into the system.

(b) FLUIDITY. Sluggish oils should first be heated before being introduced into the engine. If it be necessary to use very heavy oils, the engine should first be warmed with a more fluid fuel, and the heavy oil introduced only after the engine is hot and running well. This process should be reversed when shutting down, and the heavy oils washed out of the engine valves and pipes with a lighter oil by running a short while on these lighter oils before allowing the engine to become cold.

(c) TARRYING CONTENT. An oil should contain not more than 4 per cent of material insoluble in xylol, as a larger proportion of insoluble material will tend to form coke in the cylinders. (Ten grams of the sample mixed with 10 c.c. of xylol shaken and filtered should not show more than 0.04 increase on the filter.)

(d) COKE RESIDUE. The residue on coking should not be greater than 3 per cent. A high asphaltum or free carbon content will give considerable trouble by coking in the cylinders.

(e) FREE CARBON CONTENT. There should be not more than a trace of free carbon in the oil, as this tends to stop the valves and carbonize on the surfaces of the cylinders.

(f) VOLATILITY. At least 80 per cent should distill over at 350 deg. cent. (662 deg. fahr.), for greater than 20 per cent residue at this temperature will show a large carbon content by coking.

(g) DISTILLATION. Heavy oils and residues, although they may be successfully burned in a heavy-oil engine, should properly first be distilled (not refined) before using, as it is cheaper to prepare the oil before introducing it into the engine than it is to dismantle the engine or part of it for cleaning.

(h) FLASH POINT. The flash point should be between 60 and 100 deg. cent. (140 and 212 deg. fahr.) (Abel-Pensky closed tester). A small portion of flashy material is required to insure ignition.

(i) INCINERATING OIL. In general, a heavy oil containing no flashy material should be enlivened by about 2 per cent of a gas oil, flash point 60 to 100 deg. cent., or less, by mixing before introducing into the cylinders.

(j) SPECIFIC GRAVITY. The specific gravity in itself, although of little significance, should not be greater than 0.920 (7.67 lb. per gal.), as beyond this gravity the large proportion of heavy residual material would give trouble in the engine. In general, the boiling point or distilling proportion is of more importance.

(k) CALORIFIC VALUE. The pound-calories should not be less than 9000 (16,200 B. t. u. per pound), and the hydrogen content not less than 10 per cent, as lower values are approaching the value of pure carbon and will give poor combustion.

(l) SULPHUR CONTENT. The sulphur content should not be more than 0.75 per cent, as a greater proportion will attack the

cylinder walls and will tend to pit them, making them rough. Brass, zinc and copper are to be avoided in the surfaces exposed to combustion. Nickel steel seems to be the best resistant material.

(m) ACIDITY AND ALKALINITY CONTENT. The oil should contain no free ammonia, alkalies or mineral acids, because of their pitting effect on the surfaces exposed to the combustion.

(n) ASH CONTENT. It should contain not more than 0.05 per cent of non-combustible mineral matter, as this tends to hasten carbonization within the cylinders and prevent proper combustion.

(o) WATER CONTENT. A water content should not be greater than 1 per cent.

(p) RESIN CONTENT. The resin content should be low, as resins have a tendency to carbonize readily and will coke the cylinders.

(q) CREOSOTE CONTENT. Creosotes up to 12 per cent, although smoking to some extent, can be burned; a higher percentage gives trouble in coking.

(r) PARAFFIN CONTENT. A paraffin content above 15 per cent will give some trouble. A higher percentage of paraffin, because of the large quantity of oxygen necessary for complete combustion, will burn with difficulty.

(s) ASPHALTUM CONTENT. It must be remembered that the heavy-oil engine, at least as far as asphaltum oils are concerned, is still in its experimental stage, but it will not be unfair to assume that when the engineering difficulties are surmounted it will be practicable to burn any fuel oil containing asphaltum that is sufficiently fluid to flow, providing it be free from solid matter and water. An oil containing 21 per cent asphaltum has been successfully burned.

(t) ATOMIZATION. Fine atomization is essential, for if the fuel enter the cylinder in drops of appreciable size, being able to burn only from their surfaces, there will not be time for complete combustion. The fuel will consequently strike the sides of the cylinders and the piston head, carbonize there and coke the cylinders.

LUBRICANTS

It is important to examine carefully the lubricating oils for use in cylinders and pumps.

(a) VISCOSITY. The viscosity should be between 9 and 10 deg. (Engler) at 50 deg. cent. An oil of a much lighter viscosity would tend to burn, while one of heavier viscosity would not give as good lubrication.

(b) SOLIDIFYING POINT. The oil should be liquid at -5 deg. cent. (23 deg. fahr.) and should not freeze solid above -10 deg. cent. (14 deg. fahr.).

(c) FLASH POINT. The flash point should be between 220 to 240 deg. cent. (428 to 646 deg. fahr.).

(d) CARBONIZATION. When agitated with concentrated sulphuric acid the oil should not lose more than 10 per cent by carbonization. This sulphuric acid test gives an indication of the quantity of unsaturated hydrocarbons present.

(e) SOLUBILITY. The oil should dissolve completely and clearly in benzine.

(f) ACIDITY. It should be free from acids and alkalies, as these pit the cylinders, and free from resins and fats, as these saponify.

(g) ANIMAL AND VEGETABLE OILS. Because of their tendency to decompose, animal and vegetable oils should not be used.

Note: These specifications are being made the subject of an extensive Government Bulletin technical paper, No. 37, prepared by Irving C. Allen.

APPENDIX F-2

EUROPEAN SPECIFICATIONS

(From "Engineering," March 22, 1912)

THE DIESEL OIL ENGINE

BY DR. RUDOLPH DIESEL

The Swiss Testing Laboratory at the University of Zurich, under the direction of Professor Constam, decided to undertake the examination of the qualities and composition of all liquid fuels which can be used for Diesel engines. These researches included the following points;

1 On the physical properties, such as—
  (a) Properties when cold;
  (b) Properties on heating (boiling analysis).

2 Chemical properties, such as—
  (a) Chemical constituents;
  (b) Percentage of H_2O and ash;
  (c) Calorific power.

This laboratory is destined to become a center for the ·estigation of fuels for Diesel engines on account of the per- :tion of its equipment, the accuracy of its work and the excel- ıce of its management. The laboratory intends to publish from ɪe to time exhaustive reports of its researches.

From tests and examinations already made, power oils have en divided into the following three classes:—

1 Normal oils which can always be used—

(a)	Mineral oils freed from benzine (gas oils).	Hydrogen over 10 per cent, Calorific power per lb. over 18,000 B. t. u., No solid impurities.
(b)	Lignite tar-oils.	Hydrogen over 10 per cent, Calorific power per lb. over 17,500 B. t. u.
(c)	Fat oils from vegetable or animal sources, such as earth-nut oil, castor-oil, fish-oils, etc.	Calorific power per lb. over 15,500 B. t. u.

2 Oils which can be used only with the aid of special ›paratus—
  (a) Pit coal-tar oil;
  (b) Vertical-oven, water-gas, and oil-gas tars, probably also coke-oven tars, the tests on which have not yet been completed.

General characteristics:

Hydrogen not over 3 per cent;
Amount of free carbon not over 3 per cent;
Residue on coking not over 3 per cent;
Calorific power not under 15,500 B. t. u. per lb.

3 Oils which cannot be used—

Tars from horizontal or inclined retorts.

It must not be understood that these will not be used in Diesel engines under special conditions; but, on the whole, the above classification is accurate in the present state of development of the Diesel engine.

It is evident that for estimating the value of power oils, not only the above qualities, but all their chemical and physical properties must be considered, which is possible only after a thorough investigation of each kind of oil.

APPENDIX F-3

SPECIFICATION OF TAR OIL SUITABLE FOR DIESEL ENGINES

(From the German Tar-Production Trust at Essen-Ruhr)

1 "Tar oils should not contain more than a trace of constituents insoluble in xylol. The test on this is performed as follows: 25 grammes (0.88 oz. av.) of oil are mixed with 25 cub. cm. (1.525 cub. in.) of xylol, shaken and filtered. The filtered paper before being used is dried and weighed, and after filtration has taken place it is thoroughly washed with hot xylol. After re-drying, the weight should not be increased by more than 0.1 gramme.

2 The water contents should not exceed 1 per cent. The testing of the water contents is made by the well-known xylol method.

3 The residue of the coke should not exceed 3 per cent.

4 When performing the boiling analysis, at least 60 per cent by volume of the oil should be distilled on heating up to 300 deg. cent. The boiling and analysis should be carried out according to the rules laid down by the Trust.

5 The minimum calorific power must not be less than 15,850 B. t. u. per lb. For oils of less calorific power the purchaser has the right of deducting 2 per cent for each 180 B. t. u. below this minimum.

6 The flash point, as determined in an open crucible by Von Holde's method for lubricating oils, must not be below 65 deg. cent.

7 The oil must be quite fluid at 15 deg. cent. The purchaser has not the right to reject oils on the ground that emulsions appear after five minutes' stirring when the oil is cooled to 8 deg.

Purchasers should be urged to fit their oil-storing tanks and oil-pipes with warming arrangements to re-dissolve emulsions caused by the temperature falling below 15 deg. cent.

8 If emulsions have been caused by the cooling of the oils in the tank during transport, the purchaser must re-dissolve them by means of this apparatus.

Insoluble residues may be deducted from the weight of oil supplied."

APPENDIX G

GAS POWER SITUATION IN EUROPE

(*Extracts from Report by H. J. K. Freyn, Cons. Eng. Allis-Chalmers Co.*)

Relating to the present status of gas power in Europe, it was found that the use of such power is continually on the increase. Last year four or five of the largest gas engine manufacturers in Germany were building at the rate of 120 engines per year of not less than 1200 hp. each. They are turning out about four large engines per day. This condition is in strong contrast to that in the United States and is largely due to the fact that long experience has proven the reliability and economy of the blast furnace and coke oven gas engines as built in Germany, so that no blast furnace or steel plant can afford to install any but gas blowing and gas electric engines.

Blast furnace gas engines up to 6000 hp. are now being built in four cylinder units, with cylinder diameters up to 51 in. The only restriction as to the size is the limit of railroad clearances.

Coke oven gas engines have been developed remarkably in the last four years, and the large collieries are utilizing their surplus coke oven gas by installation of power stations of considerable size.

The producer gas engine has not kept pace with the blast furnace and coke oven gas engines. Quite recently some larger

producer gas engines are being built especially where the recovery of the by-products of the gas is being practised.

At one 3000-kw. plant in Germany, the total power cost, including everything, such as depreciation, interest, etc., is about 0.25 cents per kilowatt-hour. The operating expenses alone, including fuel at $3.00 per ton, is less than 0.7 cents per kw-hr.

In regard to the gas turbine, efforts are being made in Germany to develop the Holzwarth gas turbine, with the idea of increasing the thermal efficiency from the present 10 per cent to at least 18 or 20 per cent, and of reaching the full capacity of the machine. If these hopes are realized the gas turbine will be placed in direct competition with the steam turbine and also the reciprocating gas engine.

According to the preliminary tests on the above turbine, liquid fuel oil can be directly used in this turbine, thus doing away with the gas producer.

Information on the development of the Humphrey pump is lacking, due to the secrecy regarding tests, etc., but it is understood some difficulties have been experienced due to the variation in length of stroke of the water column. A large pump is said to have been recently started in England, but results of its operation are still lacking.

Concerning the Diesel engine, the 2-cycle engines fitted on ships have given trouble, and one concern was compelled to revert to an ordinary single-acting 4-cycle engine.

Due to the increase in the price of natural oil, all Diesel engine manufacturers have to adapt their engines to the use of tar oil, which is fast becoming the only economical liquid fuel available.

APPENDIX H

PARTIAL DIGEST OF RECENT ENGINEERING PUBLICATIONS BEARING UPON THE SUBJECT OF PRIME MOVERS OR ACCESSORY APPARATUS

"Coal: Its Consumption, Analysis, Utilization and Valuation." E. E. Somermeier. 167 pages. 8 illustrations. Published by the McGraw-Hill Book Company. Price $2.00.

This is a condensed and practical treatise on the subject of coal, dealing with the various chemical phases as indicated by the title. The information embodied is important to every large

consumer of coal, and a great many points are brought out; such, for example, as the possible bearing of the ultimate composition of the coal upon its burning qualities or characteristics, certain essential observations in sampling and analytical determinations, etc. The book is concluded by a summary of the leading coal fields of the United States.

"INTRODUCTION TO THE STUDY OF FUEL." F. J. Brislee. 256 pages. 61 illustrations. Published by D. Van Nostrand Co., New York City. Price $3.00.

It deals principally with elemental chemical reactions; the analyses of fuels and products of combustion; the use of special measuring apparatus for high temperatures, gas qualities, etc.; calculation of the proper air supply and combustion temperatures. A classification of different fuels is made, in which the distinguishing features of various grades are outlined briefly. Individual chapters are given over to discussions of producer and water gas and some of the few designs of apparatus employed; explosions and the explosion engine; testing and checking of boiler results, and the use of liquid fuel.

"STEAM BOILERS." E. M. Shealy. 350 pages. 184 illustrations. Published by McGraw-Hill Book Co.

A book prepared to provide a working understanding of the steam boiler should find a useful place in both large and small boiler rooms. The subject-matter has been presented in the simplest possible form, making it easy to be grasped by the non-technical operator. A separate chapter is given over to important boiler calculations, and also details appertaining to stays and staying, information regarding which is vital to the safety of operation.

"BOILER DRAUGHT." H. K. Pratt. 134 pages. 29 illustrations. Published by D. Van Nostrand Co., New York City. Price $1.25.

The author carefully sets forth in his abridged treatise the underlying physical theories and formulæ that apply to chimney calculation. He deals with both natural and artificial draught, forced and induced, and also features of chimney construction.

"WATER: ITS PURIFICATION AND USE IN THE INDUSTRIES." William Wallace Christie. 212 pages. 79 illustrations. Published by D. Van Nostrand & Co., New York City. Price $2.00.

While this book is of general application, as the title implies, considerable space is given over to the discussion of various treatments of boiler feed; effect of oil upon boilers; its removal, etc.

The chemical ingredients of different waters is a valuable study and along therewith is included the action of the proper re-agents.

"CENTRIFUGAL PUMPING MACHINERY: THE THEORY AND PRACTICE OF CENTRIFUGAL AND TURBINE PUMPS." Carl George de Laval. 181 pages and over 160 illustrations. Published by the McGraw-Hill Book Co., New York City. Price $3.00.

Mr. De Laval describes elaborately the kinetic theory of this type of pump, which alone necessitates five chapters. The remaining 21 chapters are devoted to operating features, design, efficiencies and the various applications of centrifugal pumps. This book should commend itself to the engineer engaged either in the use or installation of the centrifugal pumping machinery.

"CENTRAL-STATION HEATING." Byron T. Gifford. 5½ in. by 9 in. 208 pages. 37 illustrations. Published by the Heating and Ventilating Magazine Co., New York City. Price $4.00.

In this book, the advantages of central-station heating are first noted, after which follows a discussion of the engineering features of the different hot-water and steam distribution systems. The question of plant management has been given attention, as upon it the success of such an institution naturally revolves, and this has been supplemented by contingent conditions which must be understood to make the house service satisfactory. Miscellaneous data which will be of use in connection with this line of work form the tenth and concluding chapter.

"THE UNA-FLOW STEAM ENGINE." Prof. J. Stumpf. 229 pages. 250 illustrations. Published by D. Van Nostrand Co. For sale by the "Electric Journal." Price $3.50.

Prof. Stumpf describes, in a very graphic manner and in abundant detail, the very unique and useful type of steam engine developed by himself. As suggested by the title, the steam flows in a constant direction from inlet valve to exhaust ports, avoiding the variation in temperatures which produces cylinder condensation. This excellent feature has a valuable supplement in the form of valveless exhaust ports controlled by the travel of a piston. The author treats first of the thermal and constructional features and then takes up elaborately the results of numerous tests.

"DIESEL ENGINES FOR LAND AND MARINE WORK." A. P. Chalkley. 220 pages. 75 illustrations. Published by D. Van Nostrand Co. Price $3.00.

The book covers the need principally of the operator, and aims not only to give him an appreciation of the value of this type of prime mover, but presents elaborately the details of design along with the fundamental principles of operation. Chapters on testing and marine work are presented. An appendix, containing Lloyd's Insulation Rules, is included.

"HYDRAULIC TURBINES: THEIR DESIGN AND INSTALLATION." Viktor Gelpke and A. H. Van Cleve. 293 pages. 200 illustrations. Published by McGraw-Hill Book Co., New York City. Price $4.00.

The book is confined to engineering considerations entirely, and takes up in three chapters the details which enter the complete plant: Elements, principles and the mathematics of hydraulic turbines and descriptive and pictorial features of many important plants.

"ELEMENTS OF HEAT POWER ENGINEERING." C. F. Hirshfield and W. N. Barnard. 793 pages and over 480 illustrations. Published by John Wiley & Sons, New York City. Price $5.00.

This elaborate treatise, which is intended primarily as a textbook, may often be found a useful supplement for the practical knowledge necessary in operation. It takes up the theory of all types of heat, prime movers and component and auxiliary machinery.

Freyn, H. J. K.—Address on "Recent Development of Gas Power in Europe," delivered at Annual Meeting of A. S. M. E. (Journal of A. S. M. E., Feb., 1913, p. 237.)

"The Humphrey Pumps at Chingford," in issues of *Engineering* (London) of January 24 and February 14, 1913.

Clerk, Dugald—Paper on "Gas Turbine," read at Dundee Meeting (1912) of British Association for the Advancement of Science.

Yarnoll, D. R.—Paper on "Properties of V-Notch Weir Method of Water Measurement." Transactions of A. S. M. E., October, 1912.

Groat, B. F.—Paper on "Current Meter Work in connection with Water-Power Installations," in Proceedings of A. S. M. E., December, 1912.

de Ferranti, Dr. S. Z.—James Watt Anniversary Lecture, delivered at Greenock, Scotland, January 16, 1913, in regard to the High Superheat Steam Turbine.

Dowling, D. B.—Notes on the utilization of poor coal and slack. 1906. (In Journal of the Canadian Mining Institute, v. 9, pp. 321-330).

Shows that even the poorest lignite has, as a gas producer, a value equal in power production to that of a good steam coal when used in the steam plant.

Fernald, R. H.—Features of producer-gas power-plant development in Europe. 1911. 26 pp. (In United States, Bureau of Mines, Bulletin 4.)
Use of Lignite, pp. 17-21.

Gazogenes aspirants de la gasmotorenfabrik de Deutz pres Cologne. 1910. (In Le Genie, v. 57, pp. 231-233.)

Gradenwitz, Alfred.—Lignite producer-gas plants. 1905. (In Scientific American supplement, v. 60, pp. 24,900-24,901).

Neumann, H.—Die vergasung der braunkohle zu motorischen zwecken. 1906. (In Zeitschrift des Vereines Deutscher Ingenieure, v. 50, pt. 1, pp. 722-726, 898-903.)

A discussion of various forms of gas producers, purifiers and auxiliary apparatus for the generation of power gas from lignites and brown coals.

Randall, D. T., and Kreisinger, Henry.—North Dakota lignite as a fuel for power-plant boilers. 1910. 41 pp. (In United States, Bureau of Mines, Bulletin 2.)

Wilkinson, C. T.—Utilization of low-grade fuels in the gas producer. 1907. (In Cassier's Magazine, v. 33, pp. 83-85.)
Gives accurate data of tests upon four such fuels, discussing the results.

Wright, Charles L.—Briquetting tests of lignite. 1911. 64 pp. (In United States, Bureau of Mines, Bulletin 14.)
Recent literature of briquetting, p. 57-62.

Zlamal, Arnold.—Braunkohlen und torfgeneratoren für motorische zwecke. 1905. (In Zeitschrift für elektrotechnik, v. 23, pp. 521-523.)

Zwingenberger, O. K.—Utilization of low-grade fuels in the United States. 1909. (In American Institute of Chemical Engineers, v. 2, pp. 140-155.)
Deals with lignite in gas producers, as well as other low-grade fuels.

Parker, E. W.—Fuel Briquetting in 1911-1912. (Advance chapter from Mineral Resources of the United States, Calendar year 1911.)

MR. MOULTROP (continuing): After the report was written, t too late to change the text, the Chairman received a letter om the General Electric Co., criticizing one of our statements, hich is, in substance, as follows:

"We have no criticisms to offer, except as to the statement der the heading "Trouble with Turbine Blades," page 17, as llows: "Three companies report the breaking of diaphragm zzles, due to their having been cast in solid with the diaragms. The trouble was remedied by replacing diaphragms such construction with those having the blades grouped in vetailed segments, which were bolted to the diaphragm." Premably the troubles referred to occurred on Curtis turbines, d, if such is the case, I wish to state that the broken aphragm nozzles were not due to the nozzle partitions being st in solid with the diaphragms, but were accounted for by the ct that 50 per cent nickel steel was used in partitions. Preous to the use of 30 per cent nickel steel for this purpose, we ilt many turbines with nozzles cast in solid, using 3½ per nt nickel steel for nozzle partitions and a number of such achines are still in operation and have not been subject to the mplaint referred to.

Under the circumstances it can hardly be said with justice at the trouble experienced with diaphragms is due to the fact at nozzles are cast and is being remedied through the use diaphragms with removable nozzles. As a matter of fact, e are proposing, in some cases, to remedy diaphragm troubles the kind under discussion by furnishing the cast-in nozzle pe, but, in such cases, the partitions are of 3½ per cent, instead 30 per cent nickel steel.

We have developed a removable nozzle for some of our rbines and in replacing broken nozzle diaphragms, such relacement has sometimes been made with diaphragms having e removable nozzle feature, where our customers considered at this feature was worth the additional price."

Your Committee believes that the above is a correct statement of the facts and we regret the incorrect statements conined in the body of the report.

DISCUSSION

THE CHAIRMAN: The report of the Committee on Prime overs is now open for discussion.

Mr. W. L. Abbott, Chicago: Referring to the second paragraph, on page 425 of the report, since that was written the Commonwealth Edison Co. has placed an order with the General Electric Co. for a 30,000-kilowatt machine, which shows how fast we move in these things. This report was written about three months ago.

On page 435 of the report is a reference to the deterioration of steel stacks, and the statement brings out the fact that steel stacks do not corrode on the outside to any serious extent. We are careful to keep our stacks painted on the outside, and so long as they look shiny, we are satisfied with their condition. As a matter of fact, corrosion takes place on the inside at a very alarming rate, and no amount of painting on the outside is of any benefit. The only protection is first to keep the stack in service as long as possible, but a better protection is to have it lined with cement or brick with cement, in which case it is perfectly protected. Without that, and exposed to flue gas, and, particularly, if for some time of the day or some weeks or months during the year it stands idle, the life of the stack, regardless of its thickness is quite limited.

The Chairman: Is there to be any further discussion? If not, I will ask Mr. Moultrop to close.

Mr. Moultrop: In closing, as there is no discussion requiring reply, I wish to go on record in expressing the disappointment of the Committee at the lack of interest in the work we have done, if the discussion submitted can be taken as evidence. I would like to offer the suggestion that those interested in the work of this technical committee advise the Secretary of the Association of any criticisms on the past work of the Committee, and any suggestions they may have to offer to make the work of the succeeding Committee of more value to the Association.

The Chairman: The next number on the program is the Report of the Committee on Electrical Apparatus, Mr. L. L. Elden, Chairman.

REPORT OF THE COMMITTEE ON ELECTRICAL APPARATUS

During the past year your Committee has carefully followed elopments in the manufacture and use of electrical apparatus central-station service, and presents herewith an appendix, ming a part of this report, with brief comments on some of the tures of such equipment.

There has been noted a continuation of the tendency toward development of individual generating and converting units a greater capacity, as demanded by the important central-sta- 1 systems. In this connection there appears to be a very inite tendency on the part of manufacturers toward higher ative speeds in generating apparatus, an end which would m to have been accomplished satisfactorily through the employ- nt of mechanical structures of suitable design. In the attain- nt of higher capacities, the use also of improved types of insu- ng materials suitable for operation at higher temperatures and able of withstanding severe mechanical strains, has contributed gely to such success as has been secured.

With the increase in capacity of individual units, and, there- e, of generating stations, attention has been directed to the tching conditions necessarily met with in handling the enor- us amounts of energy capable of concentration at the location a fault. Investigations of the switching problem have been de from which definite information has been derived to aid the nufacturer in the creation of suitable switching apparatus to et most conditions. In certain situations the addition of cur- t limiting devices in the form of reactances has been imper- 'e, to afford relief to both switching and generating apparatus m the abnormal stresses developed by short circuits, and ing to its importance the report pays particular attention to irable limitations to be employed in the installation of such ipment.

It is believed that more attention is being given than ever ore to the perfection of the details of electrical apparatus to ire satisfactory operation, and your Committee has felt it irable to comment on some of these features.

Material improvements have unquestionably been m
60-cycle rotary converters for all uses, and it may be conf
expected that with another year's experience as a foun
this class of apparatus will permanently cast off the d
reputation it has borne in past years.

Attention is directed to the importance of the work
American Institute of Electrical Engineers in their eff
perfect the Standardization Rules relating to the rating o
trical apparatus. This is a subject of vital interest to al
of electrical apparatus, and should receive careful attent
this Association for the protection and benefit of the n
companies.

In the appendix which follows, the following subject
been treated in more or less detail, and in some cases refere
been made to important technical contributions dealing wi
cific subjects more in detail than is possible in the report.

1 Turbo-Generators
2 Reactances
3 Speed of Rotative Apparatus
4 Direct-Coupled Exciters
5 Rotary Converters
6 Motor Converters
7 Transformer Connections
8 Synchronous Condensers
9 Insulation
10 Rheostats
11 Brushes
12 End-Play Devices
13 Outdoor Substations
14 Oil Switches and Iron-Clad Switch Gear
15 Feeder Regulators
16 Relays
17 Rectifiers
18 Electrolytic Lightning Arresters
19 High-Potential Testing Apparatus

The Committee wishes to express its full appreciatio
valuable assistance rendered by both manufacturing and

ing interests through their ready response to requests for information on the specific subjects under consideration.

Committee:
L. L. ELDEN, *Chairman*
E. P. DILLON
P. JUNKERSFELD
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APPENDIX

TURBO-GENERATORS

Increase in capacity and improvement in efficiency has marked the progress of turbo-generator designs during the past year. Mention was made last year of the purchase of a 25,000-kw. unit by one of the member companies, and it may now be added that contracts for units of similar capacity have been executed by other companies.

With these generators of large capacity there must necessarily be employed suitable switching apparatus and other translating devices capable of meeting the conditions imposed in the handling of such large amounts of energy as are developed. While switching apparatus at present available appears to be capable of successfully meeting the situation, it is with no small concern that we view a further increase in the capacity of generating units, and undoubtedly recourse must be had to a more general use of current-limiting reactances in large systems than is now general practise.

In the 1911 report it was stated that manufacturers recommended, where high-voltage generation is required, that it should be accomplished by the use of a low-voltage generator and auto transformers to obtain the desired bus voltage, their reason being that high-voltage generators (15,000 volts) were not a satisfactory commercial product for either manufacturer or user.

It is of interest to note that through improvements in the insulation and design of generators, manufacturers now indicate their ability to build large high-voltage generators (up to 15,000 volts) which will furnish satisfactory service.

Reactances

Reactances in alternating-current circuits may be divided into three general classes by the functions they are expected to perform, as follows:

1 For protection against high-frequency disturbances
2 For voltage regulation and for providing synchronizing power
3 For limiting the current in case of breakdown of lines or apparatus.

Class 1 refers to reactance coils such as are used in connection with lightning arresters or other protective devices for keep-

ing out high-frequency disturbances. In such coils iron is not permissible because eddy currents set up by these high frequencies would probably be sufficient to practically eliminate the effect of the reactance.

Class 2 refers to reactances used in connection with compound-wound rotaries for voltage regulation or inserted in lines in connection with rotative apparatus, in order to give stability to synchronous motor operation and to aid in tying generating stations together over lines of high resistance. Such reactances, which also include reactance coils in arc lamps and series arc regulators, are built with iron cores.

Class 3 refers to coils which are coming to be used quite generally, especially in connection with large systems, to prevent a disastrous flow of energy into a fault. Such coils because of the large currents they must handle cannot economically be built with an iron core, as such construction would limit the effective reactance under short circuit conditions, and are, therefore, usually wound on a concrete center or on porcelain blocks.

The use of the reactances of Classes 1 and 2 has been quite well established for a great many years and the Committee, therefore, does not think it necessary to discuss these classes.

With reference to Class 3, practise is still somewhat in the evolutionary stage with respect to standards. The Committee feels that this point should receive full discussion and as a basis for such discussion suggests the following:

This third class may be further subdivided with respect to application, as follows:

(a) For use with apparatus such as generators or transformers

(b) For insertion in bus-bars of stations

(c) Feeder reactances

Subdivision (a)

The total reactance for high-speed generators will naturally vary with the size of the unit, since it is desirable to limit the total energy which may flow and which can safely be handled by an oil switch. The following values are considered conservative, the reactance in each case being total reactance, part of which may be in the machine itself and part in external coils:

For generators up to	8000-kw. capacity	...	5 pe
" " of	8000 to 15,000-kw.	" ...	8
" " "	15,000 " 20,000-kw.	" ...	10
" " over	20,000-kw.	" ...	12

The above estimated percentages apply to individua and may vary materially when several generators are ope multiple.

For transformers located in main stations it is recom that the same amounts apply as for generators.

The following course shall be pursued by purcha transformers where it is desired to include a definite am reactance in their design. In cases where the limiting current by reactance in transformers is of importance the of reactance desired should be specified.

In general it would be better not to hamper the m turing engineer in the design of a product by specifying tions which are not actually required. The strength transformer structure may properly be specified in terms excess current which the transformer must successfull stand.

Subdivision (b)

The amount of reactance to be placed in the bus-b be determined in each case by local conditions, such as of units connected to a group and arrangement of feeder large company considers 60,000-kw. generator capacity limit which it is desirable to connect to any one group (t erators themselves being equipped with reactances). I such group buses a reactance is installed having a reacti of 20 per cent on the basis of 10,000 kw.

The engineers of one large manufacturing company mend that bus reactance should be able to carry fro quarter to one-third of the kilowatt capacity on a bus secti reactive drop varying from 20 to 33 per cent, according ditions.

Subdivision (c)

Another large company is arranging to insert feede ances with a reactive value of 3 per cent in all of thei

mission feeders from the generating station, this installation being part of the general scheme of line protection.

It is contended by some engineers that feeder reactances should provide 10 to 15 per cent for reactances installed at the generator end, or, if the protected feeders form part of an interconnected network, the installation of 5 to 7 per cent reactance at each end is recommended.

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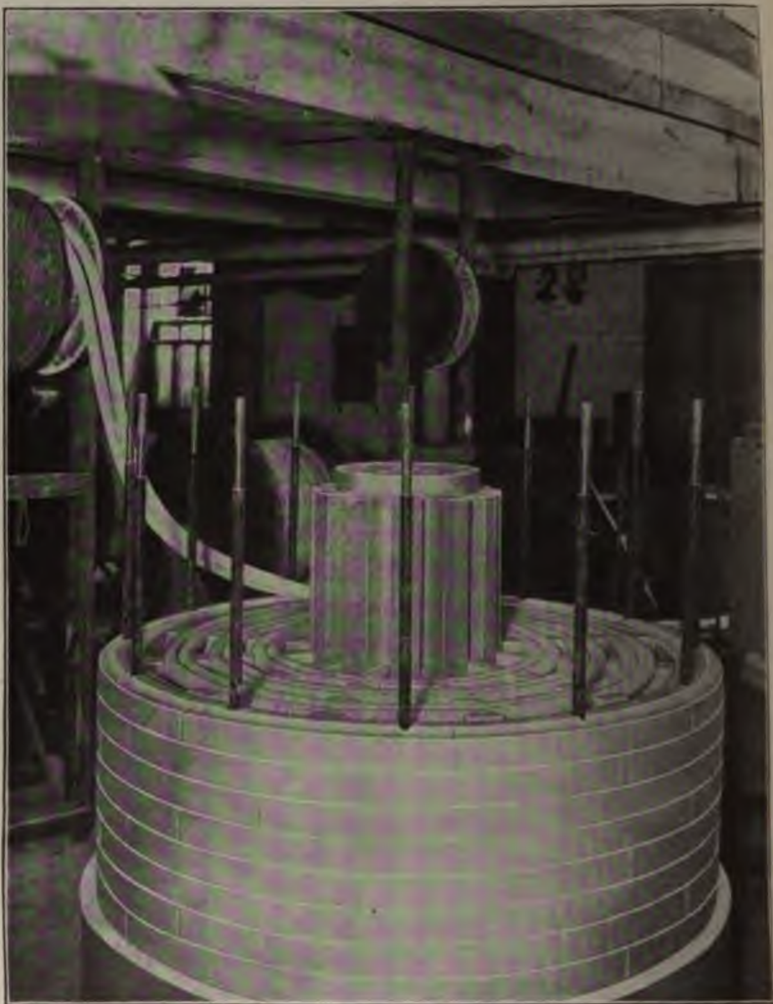


FIG. 1. REACTANCE COIL BUILT BY THE METROPOLITAN ENGINEERING CO.

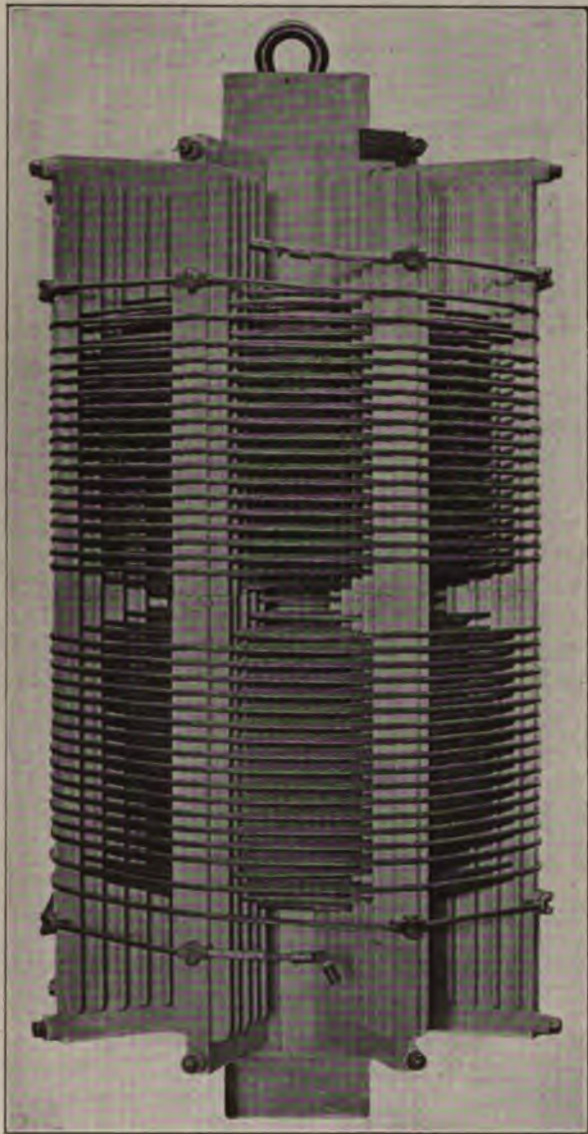


FIG. 2. CURRENT-LIMITING REACTANCE CONSTRUCTED ON CONCRETE CORE

TABLE OF CURRENT-LIMITING REACTANCES INSTALLED OR UNDER CONTRACT TO DATE

Plant	No. Coils	Location of Coils	Cycles	Capacity of Coil Kv-a.	Per Cent Reactance	System Voltage	Con. Kw.	Con. Reactance	Total Kw. on Bus.
A	27	Gen.	25	240	6	9,000	12,000	2	60,000
	12	Gen.	25	280	6	9,000	14,000	2	56,000
	6	Bus.	25	720	20	9,000	14,000	5	176,000
	9	Trans.	25	66 2/3	4	9,000	5,000	4.6	60,000
B	16	Gen.	25	30	6	2,200	1,500	2	9,000
	9	Gen.	25	42	5	2,200	2,500	5	7,500
C	6	Gen.	50	250	5	18,000	12,000	5	24,000
D	6	Gen.	25	100	5	13,200	5,000	4	20,000
								2½	
	6	Gen.	25	180	6	13,200	9,000	10	28,000
E	3	Gen.	25	177	5	11,000	10,000	6	120,000
									Future
F	12	Bus.	25	240	8	11,000	9,000	15	100,000
G	3	Gen.	50	300	6	11,000	15,000	5	75,000
	3	Gen.	50	375	7½	11,000	15,000	4	75,000
	3	Gen.	50	500	6	11,000	25,000	6	75,000
	6	Gen.	50	770	20	11,000	25,000	6	75,000
H	3	Gen.	25	300	4	13,200	15,000	6	30,000
I	9	Gen.	25	282	4.3	6,600	20,000	..	......
	12	Gen.	25	200	6.3	6,600	9,000	..	250,000
	27	Gen.	25	204	5.1	6,600	12,000	..	......
	12	Feeder	25	420	6.0	6,600	....	..	......
	24	Feeder	25	1	1.75	6,600	....	..	......
J	6	Bus.	60	1,600	18	6,600	....	..	......
	9	Feeder	60	2.4	3 1/3	6,600	....	..	120,000
									Future
K	9	Gen.	25	200	6.3	6,600	9,000	..	......
	9	Gen.	25	204	5.1	6,600	12,000	..	63,000
L	9	Gen.	60	200	6.3	6,600	9,000	..	......
	6	Gen.	60	145	6.0	6,600	5,000	..	37,000
M	9	Bus.	60	930	20.0	4,600	1,700	..	100,000
									Future

NOTE—Three coils in above table required to form a set for generator or bus.

eed of Rotative Apparatus

Attention is directed to the marked tendency of manufac-
rers toward the development of apparatus, operating at higher
eeds than were considered to be commercially desirable no
ger than one to two years ago. Turbo-generators are now
ered to operate at high speeds—for example, 5000-kw. units
3600 rev. per min., 19,000-kw. units at 1875 rev. per min., and
00-kw. units at 1500 rev. per min., and it is apparent that
final limit has not been reached.

In apparatus such as rotary converters, designing engineers
eavor to make the speed as high as is practicable in order to
uce the number of poles, improving the commutating charac-
stics by permitting larger spacing between brush arms and
ninating in a measure the sensitiveness to brush position.

The adoption of commutating poles has assisted materially
making it possible to successfully develop high-speed appa-
ıs, and in referring to 25-cycle machines of recent design it
l be noted that they are operated at approximately twice the
. per min. of the older non-commutating pole designs, although
peripheral speeds have not increased in the same proportion.

In rotary converters and other direct-current machines the
wable peripheral speed of the commutator is the limiting fac-
, and in some cases with 60-cycle converters the commutator
eds have been increased to in excess of 5000 ft. per min.,
compared with 3000 to 4000 ft. per min. in 25-cycle rotaries.

Manufacturers should especially study the elimination of
noise developed by all rotating apparatus and particularly
high-speed machines, as their use may prove prohibitive in
ny locations if not satisfactory in this respect.

While generally the manufacturer can be depended upon to
er only safe and reliable apparatus for sale, it behooves the
chaser to weigh well the advantages of apparatus which does
operate at extreme speeds.

ect-Coupled Exciters

The practise of installing direct-coupled exciters on water-
el generators has been followed in many installations in the
, and there appears to be a definitely increasing tendency to
pt similar methods in new installations. There seem to be
ımber of advantages obtained from their use where generator

speeds conform to standard exciter speeds, among which may be cited simplicity of operation and the elimination of a considerable amount of wiring and exciter switching connections, now so commonly included in station arrangements.

Applications of direct-coupled exciters to turbo-generators have also been successfully made in some cases, although there appear to be details of construction requiring the attention of manufacturers in special cases. Rugged construction is imperative in high-speed units and special care must be taken to avoid vibration, as the vibration which is permissible with alternating-current apparatus will not permit satisfactory operation of commutating machines.

In some cases additional building facilities will be required to accommodate the greater length of the complete generating unit, and it should be appreciated that the failure of any direct-coupled exciter may put the main unit out of commission unless emergency excitation connections are provided from some other source.

In general it is suggested that under proper operating conditions, with a number of large units, direct-coupled exciters are coming into use and may be found desirable on the score of economy and simplicity. Where but few generating units are installed other sources for reserve excitation are preferable. As the number of situations where such exciters are to be preferred are steadily increasing in number, your Committee calls attention thereto and urges that this matter be carefully investigated in each instance.

Figs. 3 and 4 illustrate two of the methods employed by manufacturers in applying direct-coupled exciters to generators.

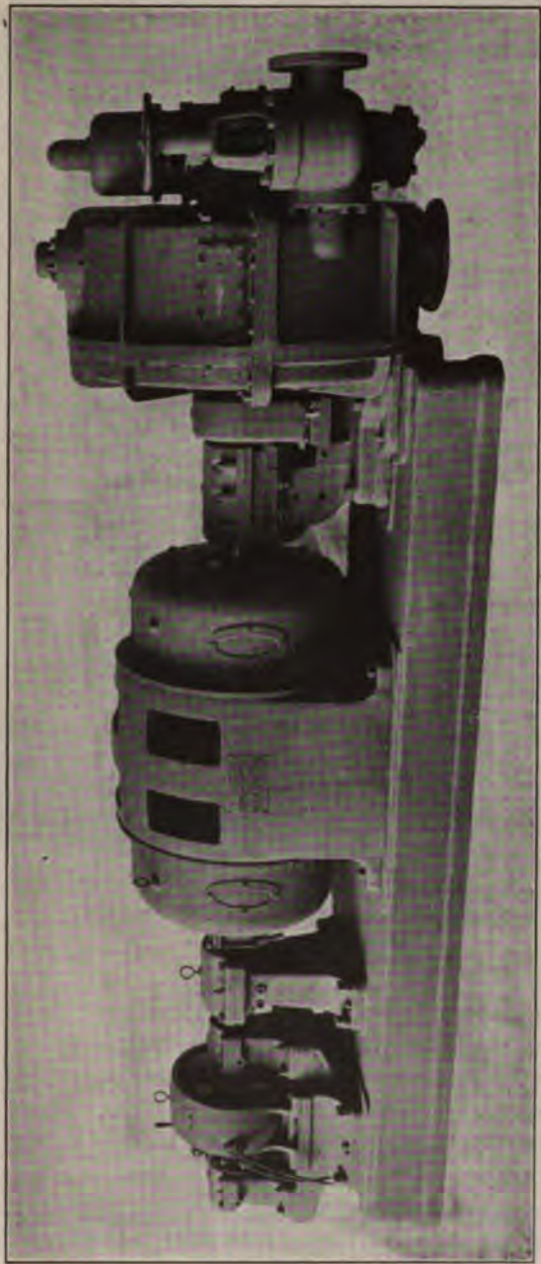


FIG. 3 DIRECT COUPLED EXCITER

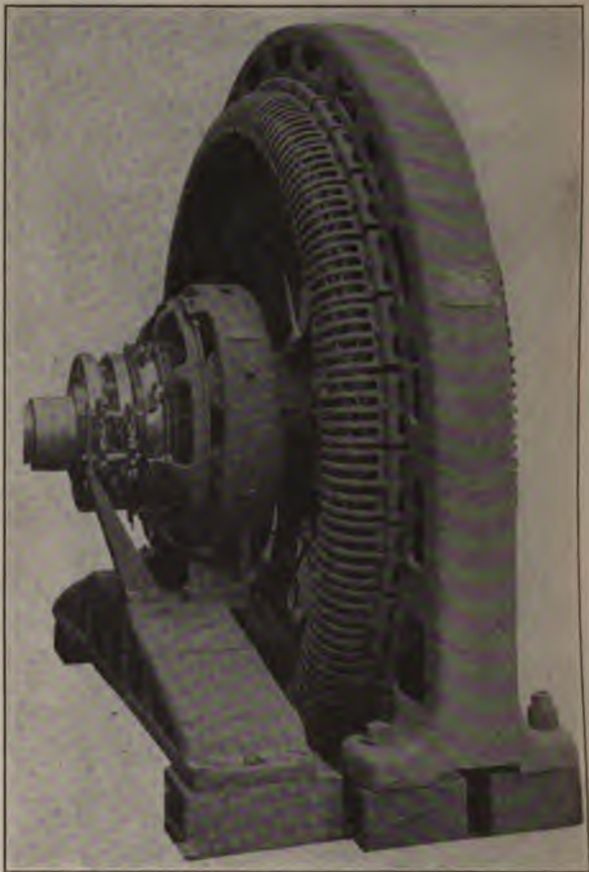


FIG. 4. DIRECT COUPLED EXCITER

Rotary Converters

In the newer designs of 25-cycle rotary converters t appear no radical changes from older designs except that t is a very definite tendency toward higher speeds and unit larger capacity. With higher speeds it has been possibl replace existing rotary converters with units of twice their ca ity without occupying additional floor space, a most econor arrangement where space is usually limited, as in city substat A number of 4000-kw., 600-volt railway rotaries are report service and a larger number on order with the manufactu

In low-voltage rotaries 3500-kw., 270-volt units are noted as the largest in use to date, and as in the previous case, others are on order.

In earlier notes on 25-cycle rotaries, reference has been made to the part played by the introduction of commutating poles into rotary design, and they continue to furnish most valuable service in assisting to maintain the excellent commutating qualities of this class of apparatus. Several cases have been reported where commutating poles have been successfully added to existing non-commutating pole machines of large capacities, with the result that the output of such machines has been increased approximately 50 per cent. In most cases such a change would also involve increasing the capacity of the step-down transformers used with such machines and create so many other special problems in connection with such work that it might prove inconvenient and uneconomical to carry out in the field.

In general, the Committee believes that proposals to change over existing rotaries should be discouraged in the majority of cases and particularly in the case of machines of small capacity where nothing can be gained by adding commutating poles without increasing the speed, which, of course, is not possible. Only in special cases should such changes be considered favorably and then with due regard to the cost and complications to be overcome.

The marked demand which has been created for 60-cycle converters has caused the development of improved machines of this type, in the design of which there have been included the use of commutating poles and, in fact, all of the good features of modern 25-cycle machines. Recourse has been had to higher speeds in the design of 60-cycle rotaries of increased capacity, and there are in operation machines of standard types of 1000 to 1500-kw. capacity on both lighting and railway systems. These newer machines are usually of either the synchronous booster or split-pole types, and while there exists some difference of opinion as to which type is most desirable, so far as their operation is reported both types seem to be rendering satisfactory service. In comparison with a rotary provided with an induction regulator, either of the two types referred to offer some advantages in the reduction of required space through the omission of the

regulator, and further a reduction in first cost as well as in cost of installation.

In summing up the situation, the Committee recommends the use of 60-cycle rotaries for railway service in the belief that such machines of modern design will perform satisfactory service.

As regards 60-cycle rotaries in sizes of 1000 kw. and over for use on large direct-current lighting systems, the Committee feels that very great progress has been made in their development during the past year. Several such machines have been installed after severe tests by manufacturers and it would seem that their success is assured, but pending further experience in actual service the Committee hesitates to present definite recommendations for their use.

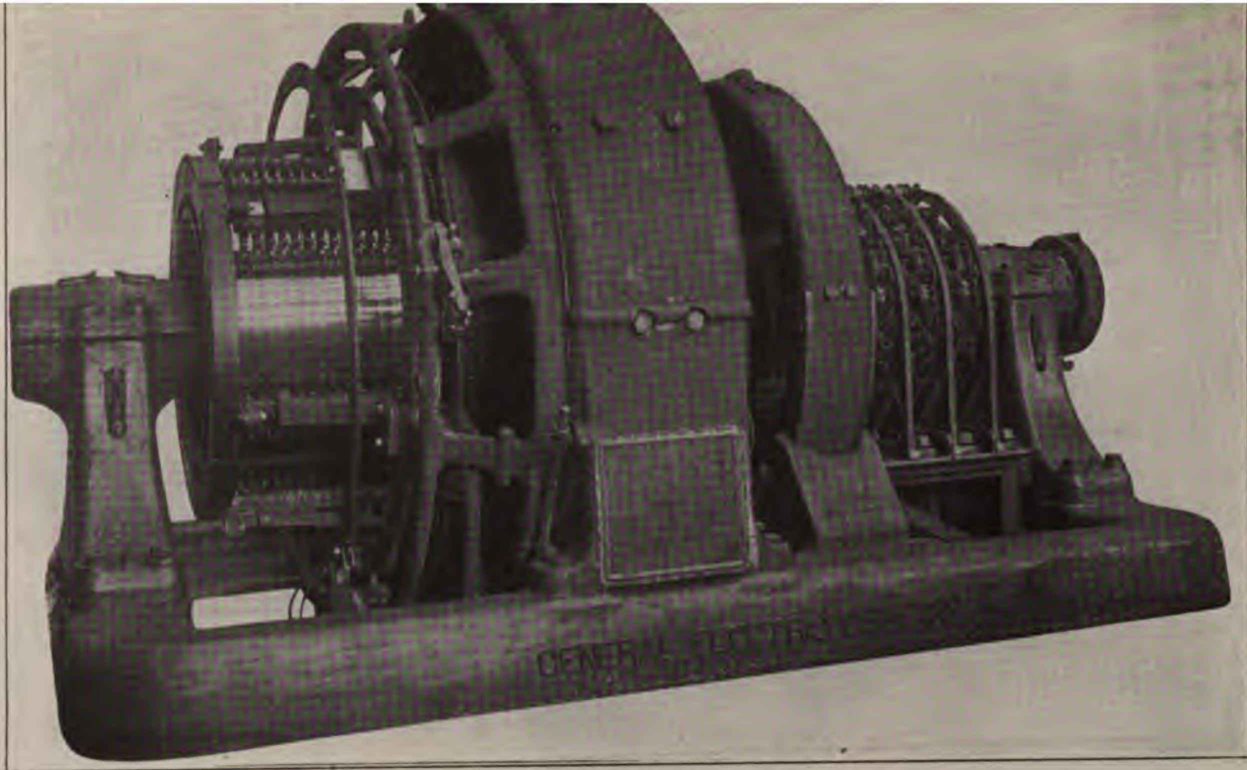
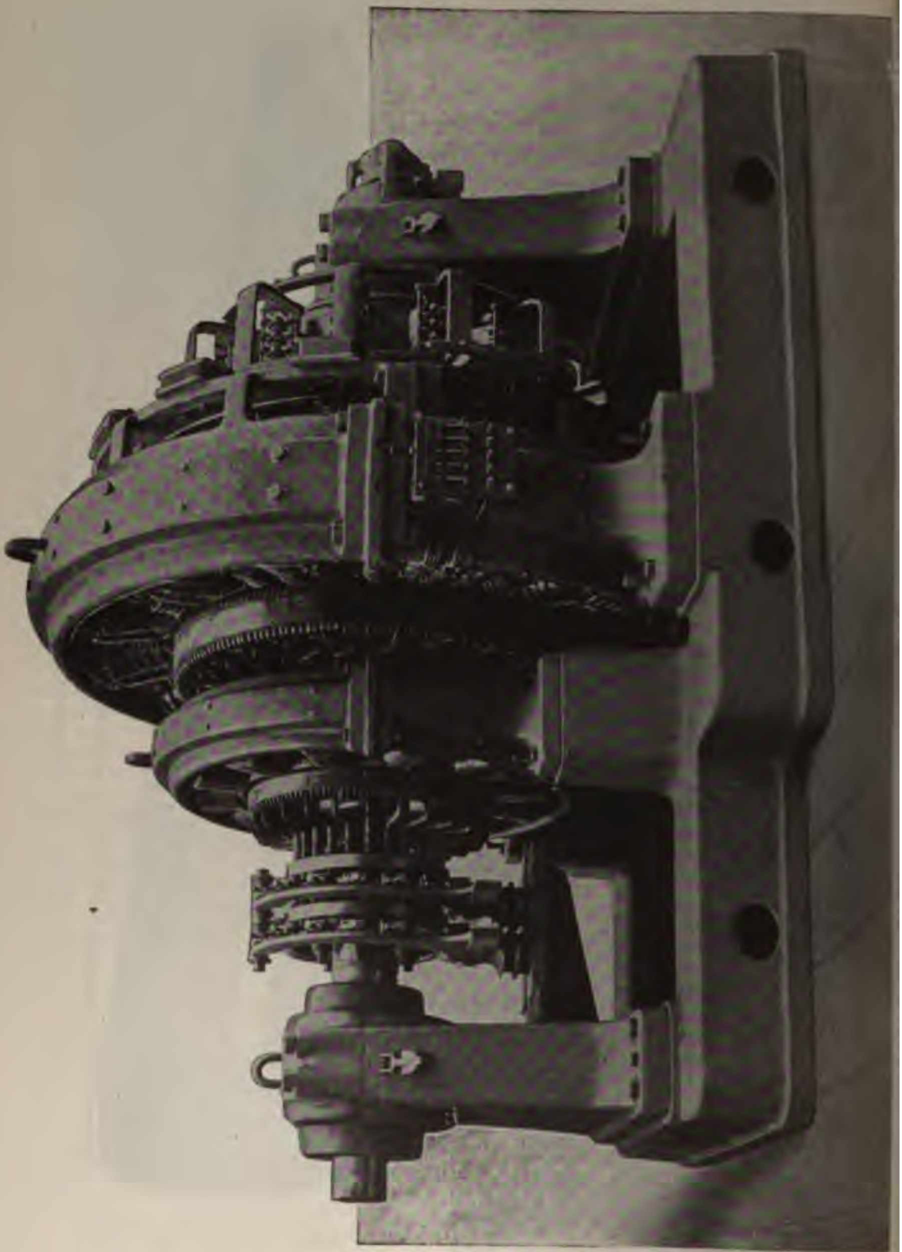


Fig. 5. Synchronous Booster Type Rotary Converter



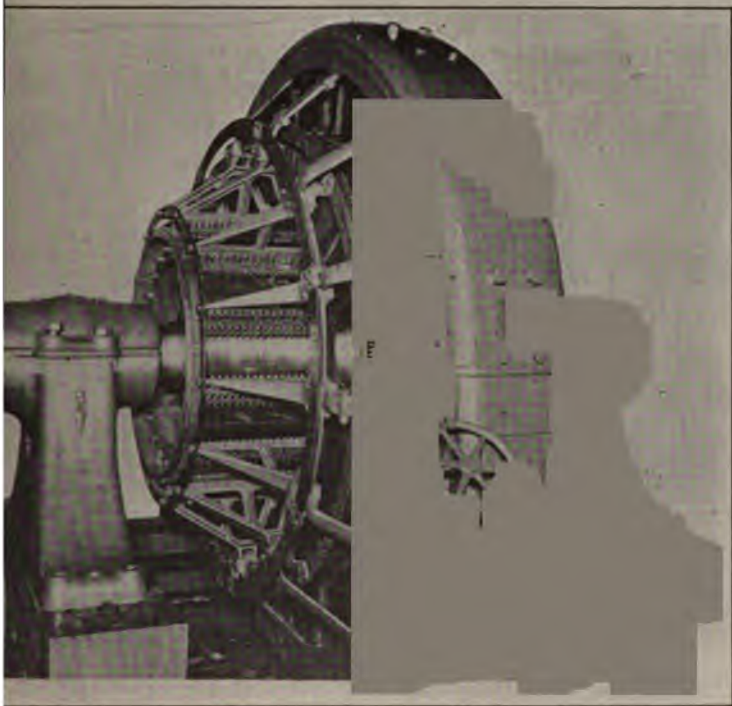
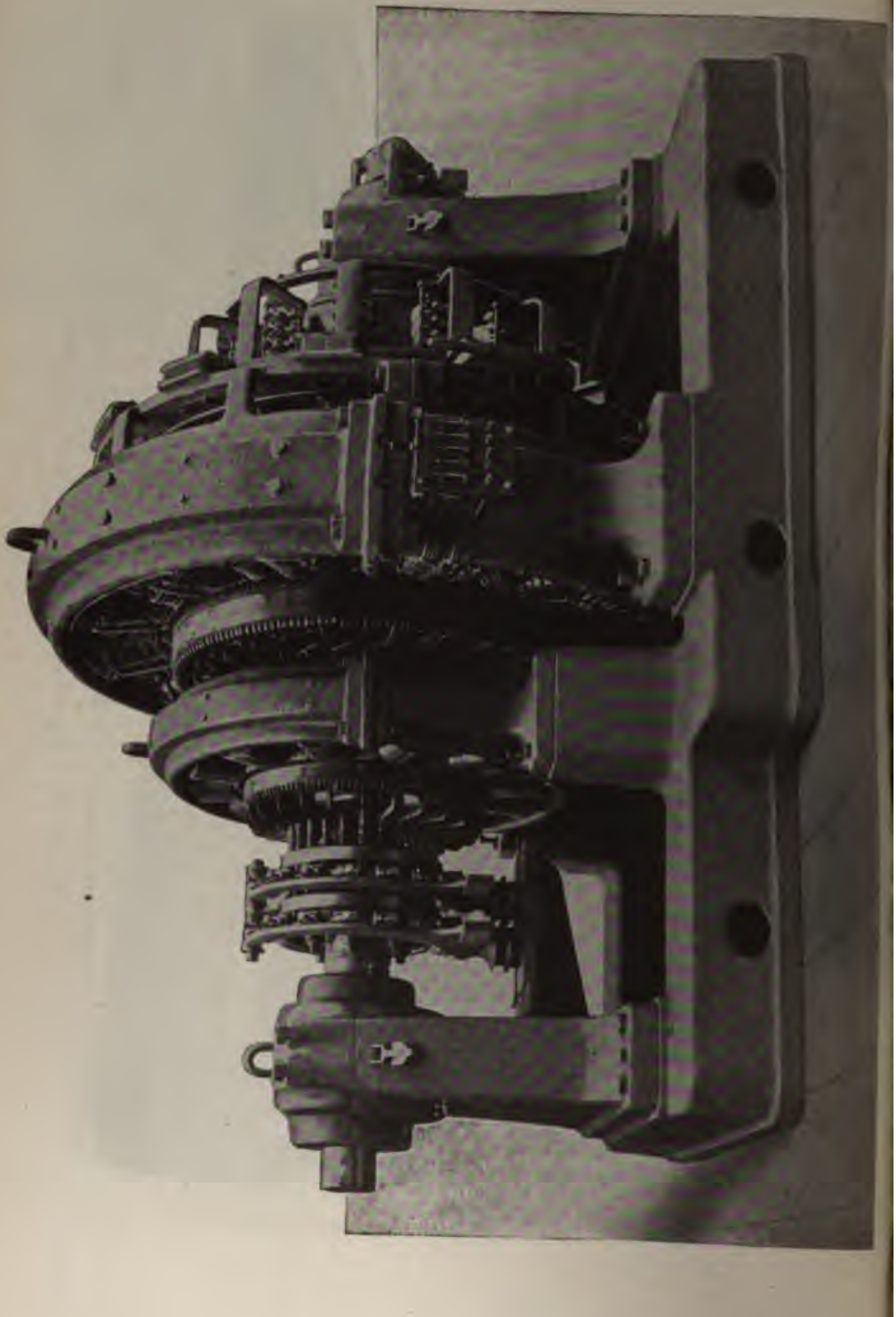


FIG. 6. SPLIT-POLE TYPE ROTARY CONVERTER



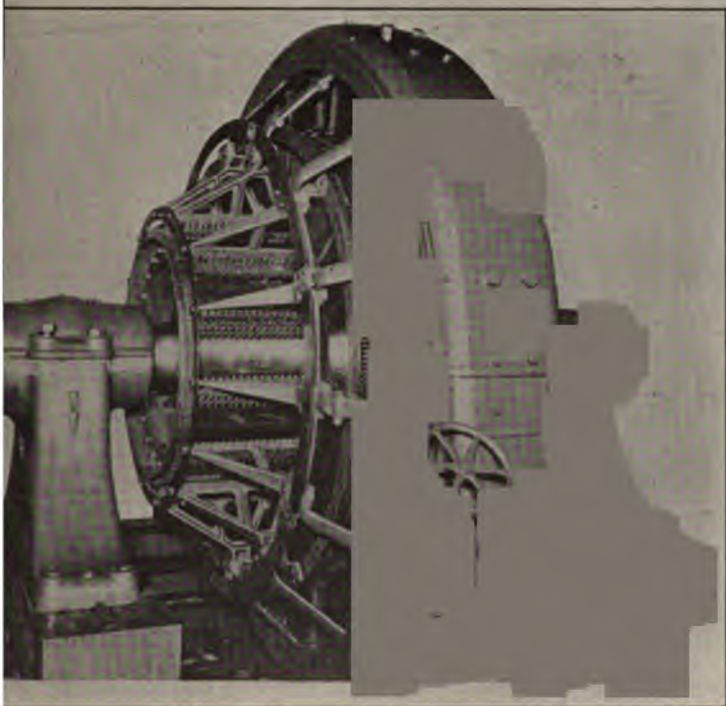


Fig. 6. Split-Pole Type Rotary Converter

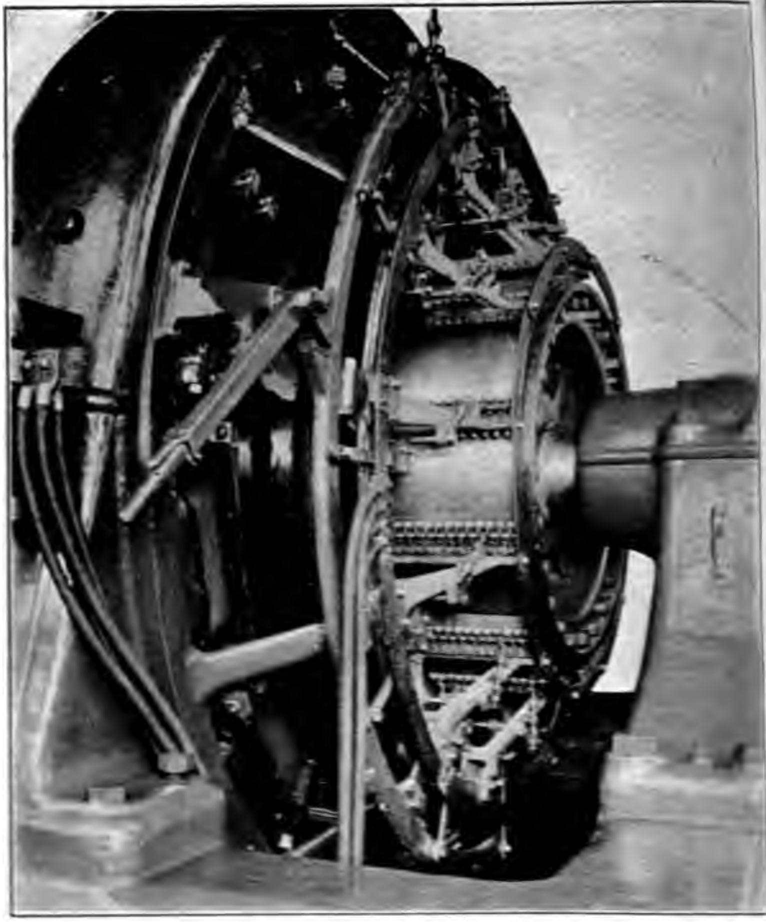


Fig. [illegible] Brush-R[illegible] [illegible] Type HCC. 12-2000-250-666 575-volt Rotary Converter

Motor Converters

The attention of the Committee has been called to the merits of a relatively new form of converting apparatus designed for the conversion of alternating current to direct current, now in general use abroad and the following characteristics are presented as emanating from the manufacturers of motor converters. This machine consists of an induction motor and a rotary converter rigidly coupled together, with the rotor winding of the

induction motor and the armature winding of the rotary connected together in parallel. In operation, the converter runs at a speed equal to half the frequency of the system, which is exceptionally favorable to commutation, and, in fact, the entire machine is of materially smaller proportions than would be a synchronous or induction motor generator of the same capacity.

The manufacturers offering the apparatus advise that it is capable of performing all the services for which rotaries or motor generators are used, including its application to 3-wire direct-current systems. In starting, the usual methods for starting from either alternating current or direct current are employed under greatly simplified arrangements. Synchronizing in particular is stated to be more easily accomplished than with any other form of converting apparatus.

In summing up the superior advantages of motor converters, the manufacturers present strong claims, and in view of these statements it is suggested that the incoming Committee be requested to investigate more fully the actual merits of the apparatus.

A COMPARISON OF MOTOR CONVERTERS WITH ROTARIES AND MOTOR GENERATORS

Characteristics	Compared with Rotaries and their Transformers	Compared with Motor Generators
Efficiency—Full load	Within 1 per cent of rotary	Better by 2½ per cent than motor generator
Half load	Within 1 per cent of rotary	Better by 4 per cent than motor generator
Quarter load	Equal to rotary	Better by 8 per cent than motor generator
Power-factor	Better than rotary with same variation of direct-current voltage	Better than induction motor generator
Starting	Simpler than rotary	Equal to induction motor generator
Synchronizing	Simpler than rotary	Better than synchronous motor generator
Regulation	Better than rotary	Simpler than synchronous motor generator
Simplicity	Simpler than rotary and transformers, which require more complicated switch-gear	Equal to motor generator
Reversal of polarity	Motor converters will not reverse their polarity	Equal to induction motor generator
	Rotaries are liable to reversal	Simpler than synchronous motor generator

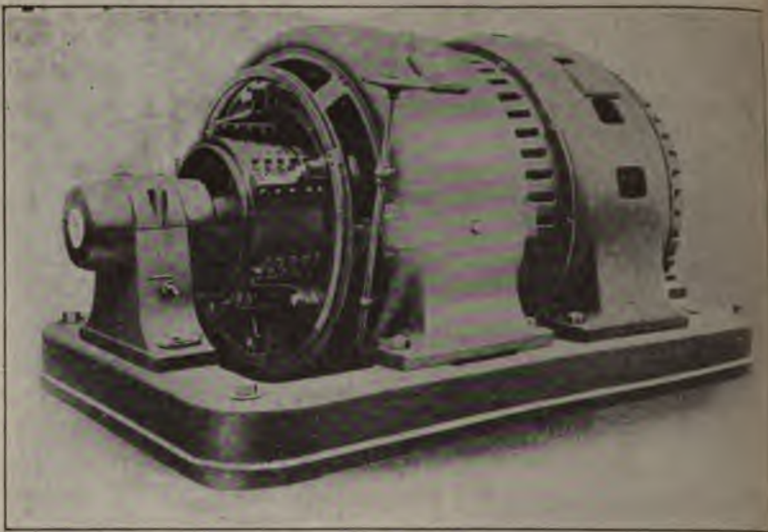


FIG. 8—MOTOR CONVERTER

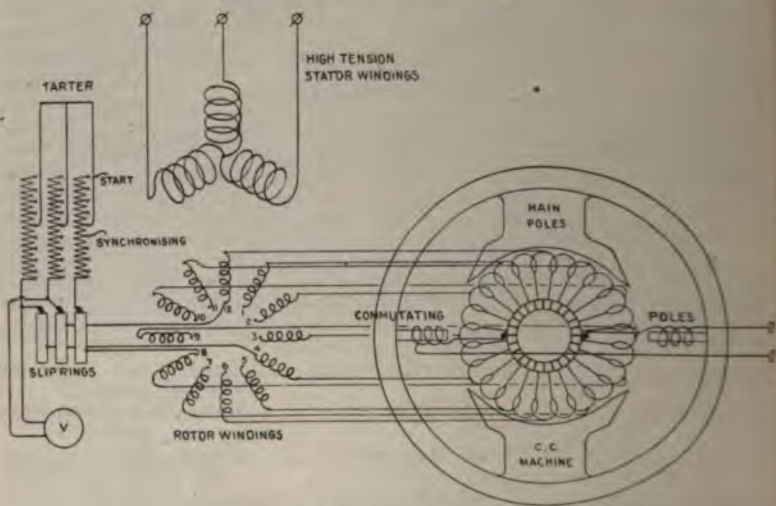


FIG. 9. DIAGRAM OF CONNECTIONS OF MOTOR CONVERTER

Transformer Connections

Many arguments have been advanced pro and con as to the best methods of connecting transformers for their several uses in stations and on the lines of our transmission systems. Although

the relative merits of the various combinations of delta and Y connections as used in specific cases are in general well known, the Committee felt that it would be of interest to include in the Proceedings of the Association a brief discussion of the subject and in order to avoid duplication of effort the matter was referred to the Transmission Committee, which has kindly consented to incorporate the desired material in its report.

Synchronous Condensers

Synchronous condensers may be divided into two classes according to the nature of their use. In one class appear those used for the regulation of transmission lines, and in the other those used for correction of power-factor on distribution systems.

In the first class a number of important installations have been made and their number is constantly increasing. One notable installation on the Pacific Coast includes two 15,000 kilovolt-ampere condensers for voltage regulation on a 50-cycle, 150,000-volt transmission system, where they will be used not only to compensate for low power-factor but for the excessive charging currents developed by such a system under light or no-load conditions. In some instances turbo-generators in reserve steam plants, auxiliary to transmission systems, are used to advantage as condensers for power-factor correction and regulating purposes.

Where synchronous condensers are employed in connection with distribution systems, it is usually to compensate for unsatisfactory conditions created by consumers' apparatus. While this is always a feasible method of improving power-factor conditions, it should be resorted to only as a last extreme after all other available schemes for improving operating conditions have been tried.

Low power-factor, except in special cases, is usually the result of the prevailing tendency to install larger motors than are actually required. In certain classes of service, owing to their nature, low power-factors are necessarily developed and may require special attention for improvement, but aside from these cases it appears possible in the majority of situations to materially improve the operating conditions by a more intelligent application of power-consuming devices. It has been found

desirable in the experience of some companies to enter into special agreements with consumers wherein favorable rates have been established for the maintenance of high power-factors by consumers' apparatus.

In the past, it has been suggested that a substantial number of undesirable low power-factor installations could have been avoided by the use of synchronous motors in place of induction motors. That this has not been done has been due to the comparatively poor starting torque and pull-in torque of the standard synchronous motor, as compared with the induction motor. Further, the increased cost of the synchronous motor and the greater care required by it have prevented its use in many cases. The Committee is advised by one manufacturer that synchronous motors in sizes of 50 kw. or larger, may now be built with starting and pull-in torque equal to if not better than that of induction motors, through the adoption of designs materially different from those now employed in standard synchronous apparatus.

Here again the question of increased cost is encountered and it is contended in some circles that the central station should take some part in adjusting this difference in cost of apparatus, inasmuch as it is materially benefited by the improvement in operating conditions and a reduction in investment for generating and distribution equipment.

It is questionable just what is the proper course to pursue in adjusting the relations between a supply company and its customers in low power-factor installations, and it is recommended that the Rate Committee of the Association be requested to consider the subject.

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Insulation

No more important subject can be considered by this Association than the quality and durability of the insulation included

in the construction of apparatus regularly employed in the generation and distribution of electrical energy. It is gratifying to note that the manufacturers are working as a unit to further improve their product in this respect. We are assured that recent studies and experiments on insulating material are to lead to the employment of materials calculated to considerably increase the useful life of windings and possibly their capacity, owing to the higher temperatures at which apparatus may be operated.

The question of the rating of electrical apparatus, with which is included the defining of safe temperatures at which the several classes of insulation may safely be operated, is now before the A. I. E. E. Committee on Standards, and upon the invitation of the Institute this Association has made certain recommendations on the points at issue, all tending to conservative temperature ratings.

Upon the completion of the A. I. E. E. Committee's exhaustive study of this subject, we may expect some definite recommendations which will serve as a guide for both manufacturers and operators in the design and operation of electrical apparatus, under conditions tending to long life and reliable service.

Rheostats

Certain member companies have reported incipient troubles with rheostat construction and methods of installation, which have resulted in accidents or interruptions to service of great importance.

In one case it has been deemed desirable to specify the maximum drop which shall exist across balancer and booster fields when the rheostat is all out, as a precaution against such machines running away. In this connection it is the practise of one company to furnish a locking bolt on the field switches to prevent the operator from opening such switches without due consideration. Recent installations include in many cases an indicating device on the switchboard showing the operator the position of the rheostat contact arms at all times.

In the construction of rheostats for use on direct-current generators and rotary converters, the present practise seems to demand that the voltage be regulated within one-tenth of 1 per cent. This requirement necessitates the use of from 48 to 60 steps in the rheostat according to the method of control employed,

that is, whether by hand or by automatic devices such as the Tirrill regulator. These requirements naturally vary with different classes of apparatus, but generally fall within the limits specified.

Rheostats as constructed for large units are heat-producing units of considerable value, and as such resistance material is operated at temperatures approaching 300 deg. fahr., their installation should be carefully considered to eliminate fire risk.

It is believed that with the increasing importance of the rheostat as forming a part of equipments of large capacity, more attention should be paid to its installation and maintenance than appears to be the case in many central stations.

Brushes

The Committee submits the following statements as a résumé of the present state of the industry in the application of brushes to standard existing designs of commutating apparatus, and at the same time advises that cases may arise where it will be found necessary to deviate materially from the practise here outlined.

The Hard Carbon Brush

This brush is selected usually on account of its hardness and good wearing qualities both as to the brush itself and the effect upon the commutator. No initial lubrication is necessary, it being expected that the station engineer will use his judgment as to the necessity of lubricating the commutator. If lubrication is applied carelessly or too freely the brushes will become gummed up and stick in the holders, causing sparking and pitting of both the brush and commutator surfaces. The usual current density allowable for this brush is 35 amperes per sq. in. at normal speeds. It is customary to use it on all slow and moderate speed machines, such as direct-connected engine-driven generators at all voltages, direct-connected exciters, slow-speed turbines, and, in connection with graphite brushes, on motor- generator sets above 500 kw. at 300 volts or more, where it is undesirable to operate with grooved commutators. This is done because the graphite brush does not have sufficient abrasive material in its make-up to keep the mica in the commutator worn down uniformly with the copper, the usual proportion of two-thirds hard carbon and one-third graphite brushes being employed in such cases. It has been found necessary to use hard brushes

on high-voltage commutators in many cases, due to the higher percentage of mica used in such commutators.

The Treated Hard Carbon Brush

On high-speed machines where it is desirable to have self-lubricating brushes, the hard carbon brush as described above is impregnated with oil or grease. This provides sufficient lubrication until the commutator surface is in good operative condition, after which it is necessary only to keep the commutator clean and wipe the brushes and brush-holders occasionally. With this type of brush, however, there is great possibility of lack of uniformity in density, which results in some of the brushes absorbing more of the lubricating agent than others, bringing about the condition mentioned above, due to improper hand lubrication. To overcome this condition and also to eliminate the necessity of having to use mixed brushes on ungrooved commutators, it is aimed to introduce a brush with such a mixture of carbon and graphite as will combine mica wearing and lubricating qualities in one. The treated hard-carbon brush is used on railway and mill type motors, motor generator sets of all sizes up to and including 500 kw. at and above 300 volts, and up to and including 150 kw. below 300 volts. With this type of brush, a current density of 35 amperes per sq. in. is permissible.

The Graphite Brush

This brush can be used in cases where relatively high density, viz., 50 amperes per sq. in., is necessary, and it possesses excellent lubricating qualities, having a low coefficient of friction and contact resistance as compared with the carbon brush. It is adapted to high-speed commutators of low voltage machines in order to reduce the losses between commutator and brush, and at the same time keep the size of the commutator within reasonable limits. It is used on motor generator sets below 300 volts and of more than 750-kw. capacity. It can be placed on grooved commutators only, except where they are used in connection with hard carbon brushes to wear down the mica as previously explained. They are also used on direct-current turbo-generators and high-speed field collector rings.

The Copper Graphite Brush

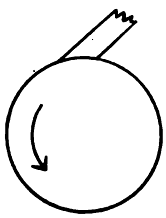
This is a metal brush made up of a combination of copper and graphite, the original mixture having been developed for use

on the collector rings of rotary converters where it now has its most general application, giving excellent and successful service. These brushes have a low contact resistance, and a current density of 125 amperes per sq. in. is allowable.

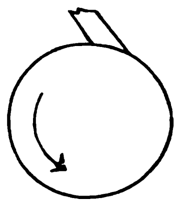
A modification of this mixture is also used on commutators of very low voltage direct-current machines, such as for electrolytic service, and for automobile generators and starting motors. This modified mixture can be used with a current density of 100 amperes per sq. in.

Operation of Brushes

On commutators having a peripheral speed of 3500 to 4000 ft. per min., 15 deg. brush-holders should be used and the brushes should be set leading at 450 rev. per min. or less, and trailing for more than 450 rev. per min. Commutators operating above 4000 ft. per min. should use 30 to 37½ deg. leading brushes. In all cases where mixed brushes, that is, part carbon brushes and part graphite brushes are used, the brush angle should be 15 deg. and they should be operated trailing.



TRAILING



LEADING

Too much emphasis cannot be placed on the proper care and oiling of brushes to insure proper lubrication, as past experience shows that lack of care or knowledge of this subject has been responsible for unnecessary failures of apparatus. Recent statistics show the life of carbon brushes to average approximately 35,000 hours, or from 9 to 10 years, under ordinary average hours of operation. The life of copper leaf brushes in connection with special lubricating brushes when used on collector rings appears to average about 76,000 hours, equivalent to 20 years of ordinary operation.

End-Play Devices

End-play devices are usually of a mechanical or magnetic design, and where employed are arranged to create and sustain

a slow longitudinal oscillation of the shaft of a generator to which it is connected. This action tends to prevent the grooving and tracking of the commutator by the brushes, and when supplemented by proper staggering of the brushes, the grooving of the commutator is usually prevented.

Improvements in brushes, as referred to elsewhere, have tended to greatly reduce the wear of commutators, but the necessity of operating brushes at higher current densities has largely counterbalanced the gains effected by the introduction of higher grade brushes. Difficulties with mechanical end-play devices have been confined largely to breakage of springs, wearing and breaking of raceways and steel balls, and other minor failures which have materially affected their efficiency. Magnetic devices have failed through breaking of flexible connections, burning of terminal contacts and burning out of series resistance.

Notwithstanding the trouble encountered with these devices and the great improvements effected in the construction and wearing qualities of commutators and brushes, it is the unanimous opinion of both manufacturers and operating engineers that end-play devices should be retained on certain classes of rotating apparatus, such as rotary converters and motor generators.

Outdoor Substations

In the previous report, mention was made of the increasing tendency toward the use of outdoor switching stations. The installation of stations of this character is not limited to any particular section of the country, as they are in successful operation in northern regions where subjected to heavy snow and sleet storms, and in southern latitudes where intense heat and heavy rain fall are regularly encountered. Investigation of the merit of these installations reveals certain advantages and disadvantages to be met with in such construction as compared with indoor stations.

Advantages

(1) Lower first cost
(2) Extensions made at less cost
(3) Reduction of fire risk
(4) Cooling of air blast and oil-cooled transformers found to be more efficient

Disadvantages

(1) Trouble from moisture

(2) Interference with apparatus by outside parties

(3) Repair and handling of apparatus, especially in bad weather.

So far as can be learned, manufacturers have made definite progress in so designing the switching and transforming apparatus for outdoor installation that there is little if any danger of apparatus supplied for such purposes proving other than satisfactory.

Troubles have been encountered with the partial solidification of switch and transformer oils at low temperatures, but these have been remedied by the development of a suitable oil for such conditions.

Collections of moisture at transformer and switch terminals, due to variations in temperature, have been the cause of many failures, but with the re-design of the apparatus for more liberal factors of safety, all such troubles appear to be eliminated.

A most important feature of an outdoor station is the protection of the apparatus from lightning discharges. Until recently the aluminum arrester has not been suitable for installation out-of-doors in cold climates, yet it is practically the only satisfactory form of lightning arrester equipment for the protection of high-tension switching and converting apparatus. Recent developments have made available a form of electrolyte for aluminum arresters which is non-freezing at temperatures in excess of 20 deg. fahr. below freezing, thereby permitting the use of such arresters in the majority of cases.

Aside from the larger outdoor substations there appears to be an increased use of transmission lines for distribution purposes, which has led to numerous smaller installations of outdoor equipment in capacities not warranting the designation of substations. While manufacturers offer switching and transforming apparatus suited to meet practically any supply requirement, its application to these situations requires all the attention given to larger installations. Transformers are available of 10 kw. and over, arranged to transform for local distribution from pressures as high as 66,000 volts to 110-220 volts, and many such units are in use; while self-cooled oil transformers up to 3000-kw. capacity are regularly manufactured for such purposes.

Where metering of energy is necessary it should be done on the secondary side, since metering of primary current is to be avoided in outdoor substations wherever possible, such complications defeating the object of these installations, where simplicity is of prime importance.

Your Committee recommends careful consideration of this form of installation as affording another means for the economical supply of service under favorable conditions.

Figs. 10 and 11 illustrate types of transformers usually employed in outdoor substations.

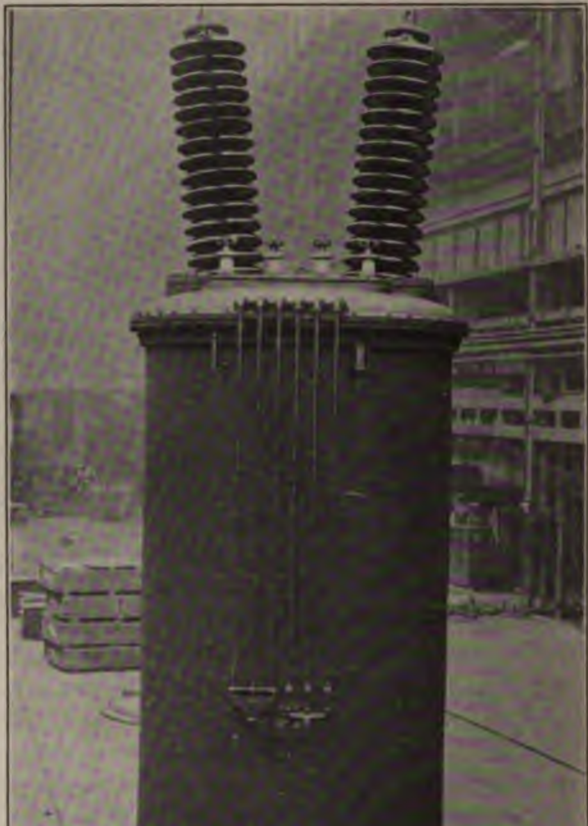
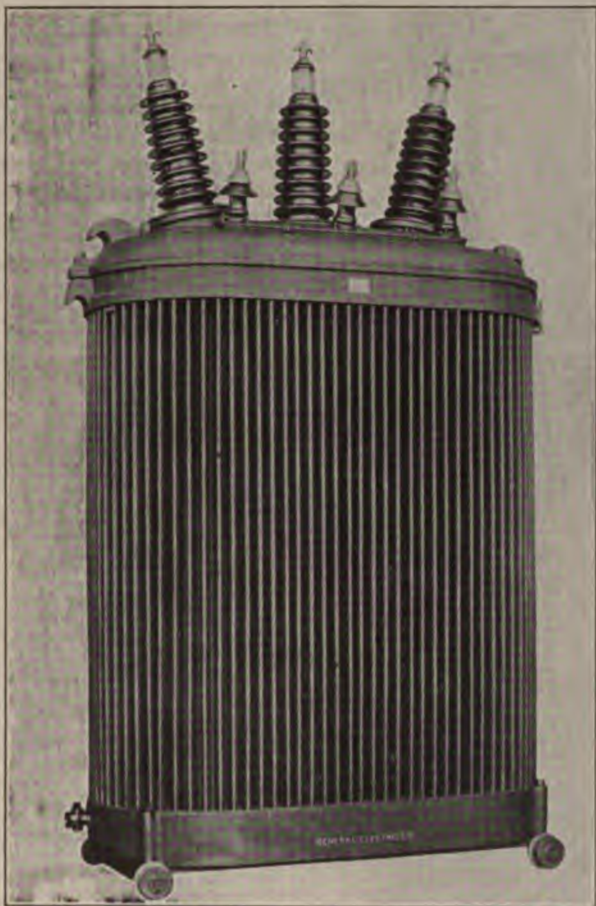


FIG. 10. 2000-KILOVOLT-AMPERE 150,000-VOLT OUTDOOR TYPE TRANSFORM



G. 11. 250-Kilovolt-ampere 88,000-volt Ootdoor Type Transformer

Oil Switches and Iron-Clad Switch Gear

Last year's report indicated considerable progress in the details of oil-switch construction, largely as a result of several very complete tests carried on in Chicago and at Niagara Falls, and the circuit opening problem is now better understood. As a result of the information acquired from these tests, manufacturers of switches have made many improvements in design, thereby effecting marked progress in switching apparatus. Changes in baffling and similar details have resulted in a substantial increase in rupturing capacity. In some instances a small reactance is automatically cut into circuit after the main contact is opened and before the final break of the circuit is complete, thus limiting the current and making it unnecessary to break the full power of the circuit on the last contact. This switch or circuit-breaker in reality consists of a double circuit-breaker having two complete sets of contacts and self-contained reactance coils, included in and operated by a single mechanism. One set of the contacts are known as main contacts and normally conduct the total current when the breaker is closed. These are shunted by appropriate reactance coils and an additional set of contacts, which carry current only during the operation of the breaker in the act of closing or opening. This type of breaker is very promising and will undoubtedly occupy an important position among devices of this character employed in heavy duty work.

One of the details which has received much attention is the matter of disconnectives immediately outside of the switch. In one development the entire switch is arranged to be dropped about six inches, thereby disengaging the connections directly above the oil tanks. One of the switches illustrated in last year's report is so arranged that each tank, with all of the operating mechanism within it, can be drawn forward on wheels after the disconnecting blades above the insulators are opened. The feature of rapid removability of the switch from the remainder of the structure has much in its favor and should receive more attention in the future.

Brief mention was made in last year's report of a type of English iron-clad switch gear. American manufacturers are now actively engaged in preparing a line of enclosed sectional switch gear for varied purposes. Such enclosed switch gear, built either in cabinet form, like many of the European switchboards, or, pre-

ferably, in some simpler modification of that construction, should find ready use in many American installations. Each switch gear and instrument cabinet section should be complete in itself, ready for a similar section to be placed on either side with the absolute minimum of erecting work, like a sectional bookcase. This would result in standardizing switchboard construction to a greater extent and would reduce the total cost, since a great deal of work can be done wholesale in factories much more economically than it can be in individual installations.

The Committee again emphasizes the importance of developing rapid-opening switches, these being of great value in certain situations. In making this statement, it is admitted that experience shows that the rapid rupturing of currents of large volume in connection with underground cable systems may develop abnormal rises of potential or surges dangerous to other apparatus. Nevertheless there are situations where it is imperative that rapid action be obtained and a sufficient factor of safety must be maintained elsewhere in the system to permit such operation.

Tests of standard circuit-breakers reveal operating speeds varying from a minimum of 0.09 seconds to an average of 0.3 to 0.6 seconds, depending on the type of circuit-breaker and relay and the method of tripping.

Detailed reports of tests on oil switches and circuit-breakers may be found in the following publications:

Paper, Messrs. Schuchardt and Schweitzer, A. I. E. E. Proceedings, 1911

Paper, Mr. E. B. Merriam, A. I. E. E. Proceedings, 1911.

Paper, J. N. Mahoney, *Electrical Journal,* Sept., 1912

Automatic Feeder Regulators

Refinements in mechanical construction and some slight improvement in efficiency constitute the principal changes in feeder regulating apparatus since the last report was presented.

A number of failures of induction regulators have been reported during the year, and in almost every case the failure was attributed to insufficient insulation, due principally to the use of poor materials. The attention of the manufacturers has been directed to these failures and it is believed that similar troubles will not develop in regulators of recent construction.

The types of regulators available are confined to the induction and so-called B.R. or "switch" type. In the induction type the speed of operation from full boost to full buck appears to be standardized at approximately nine to ten seconds, and where the duty required does not involve regulating widely and rapidly varying motor loads, this regulator is entirely satisfactory.

In certain situations where both lighting and power service are supplied from the same feeder, it has been found desirable and necessary to resort to the more rapid B.R. type of regulator to insure freedom from perceptible variations in lighting pressure. As is well known, the B.R. regulator, owing to its lighter moving parts and method of operation, completes full travel from buck to boost in three to five seconds, accomplishing thereby most perfect regulation.

When considering the merits of the two types of regulators for any class of service, it should be appreciated that the recovery of the B.R. regulator is a straight line curve and at a fixed rate, whereas the induction regulator curve is relatively flat at the start, due to the comparatively heavy effort required to accelerate its moving parts. As the rapidity of correction is most important in all regulating apparatus, this feature of operation at the start is worthy of careful consideration, and should be balanced against the increased cost of the more rapid regulator.

One manufacturer has developed an automatic single-phase induction regulator of small capacity, shown in Fig. 12, arranged for installation on a pole in exactly the same manner as a transformer. This regulator, while in every way comparable with the ordinary induction regulator as regards efficiency and construction, has the entire operating mechanism, including driving motor and voltage relay, assembled within a suitable iron weatherproof case, and when installed it may be expected to operate for long periods without requiring other than occasional inspection. This form of regulator should prove particularly useful in suburban distribution on feeder circuits extending over wide areas of sparsely settled territory. Its use will make possible the individual regulation of taps from the main feeder for lighting service for small villages or groups of consumers, entirely apart from such regulation as is given to other parts of the same feeder at the station, and in that way make possible the use of transformers and lamps of similar voltage throughout such distribution systems.

Relays

Aside from the introduction of certain refinements in construction which contribute to higher accuracy in operation, there have been no new developments of note during the year. Induction, bellows and motor type relays continue to furnish inverse

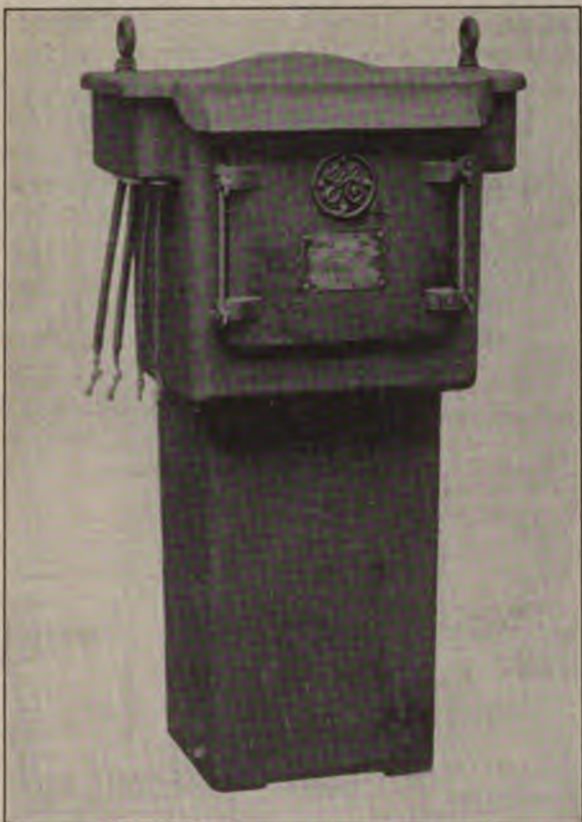


FIG. 12. POLE TYPE AUTOMATIC FEEDER REGULATOR

time and definite time limit protection from overloads, with varying degrees of success. It is apparent, however, that discriminating users are exhibiting a preference for the more accurate devices in their selection of protective apparatus.

In close relation to the successful operation of relays is the time required for the main oil switch to open after the tripping

circuit is closed by the relay. More and more experience shows tnat a most important factor in protective equipment is a rapid opening switch, and progress in that direction will go far to help solve the relay problem satisfactorily.

Reports of additional applications of the Merz-Price system of balanced protection have reached the Committee, and it may be stated that so far as is known the use of this system has been uniformly successful wherever tried in this country.

In answer to an urgent demand for a reliable alternating-current reverse current relay, one manufacturer has developed a device of that character for which broad claims are made. Constructed on the principle of the watt-hour meter, this relay is said to be effective in preventing the tripping of the main switch so long as the current is flowing in the right direction, even although both voltage and power-factor drop to 2 per cent of their normal value. It is claimed that, owing to its reliable operation and unfailing ability to properly select between overload and reverse current, it will prove entirely satisfactory for the protection of parallel feeders, and in most situations where tandem and ring systems of feeders are operated. As yet, the Committee has no information covering the actual use of this relay in commercial service.

In general this subject is receiving constant attention from manufacturers and individuals, some of whom have evolved meritorious methods of protecting electric supply systems, and it is hoped that the result of their efforts will be a solution of some of the difficulties now experienced in providing full protection for our apparatus.

Rectifiers

Aside from the development of minor defects in the construction of the coils as supplied by one manufacturer, there have been no reports of mechanical failures of rectifiers during the year. These troubles, being due to insufficient insulation, have been quickly remedied and may not be expected to appear again. The operation of the tubes still leaves much to be desired if we are to obtain a more even performance in service, and the elimination of the frequent service interruptions due to the momentary dropping of load in the tubes. So serious has this feature of rectifier operation on high voltage circuits of 6000 to 7000 volts

become, that active efforts are being made to effect an improvement in this respect. Experiments are being conducted in the plant of one of the member companies, in which the effect of more frequent resting of tubes, and the use of tubes of modified designs are being carefully observed both as regards increase of life and freedom from service interruptions.

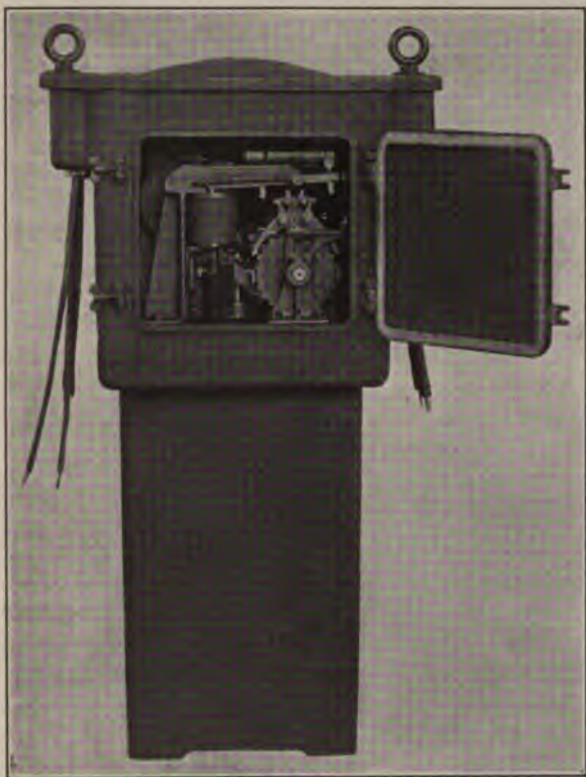


FIG. 13. POLE TYPE AUTOMATIC FEEDER REGULATOR FOR OUTDOOR SERVICE

Among other experiments, the effect of increasing the number of tubes in series on a specified load has been carefully studied, as has also the application of a duplicate set of tubes in the same tube tank connected in multiple, but so arranged that only one set of tubes is actually in service at one time. In action, should one of the active tubes fail either permanently or momentarily, the

load is automatically transferred to the duplicate set of tubes without interrupting the circuit operated by the rectifier. This is accomplished by the action of the automatic shaking device which comes into action instantly to shake the tubes if there is any reduction of the current in the series circuit below a predetermined value. As operated experimentally, this arrangement is particularly effective and it is believed that with the perfection of the mechanical features of the new form of equipment, which must of necessity be developed to include the additional apparatus, the great majority of the interruptions now experienced from tube failures will be eliminated, thus placing the apparatus on a high plane of reliability for commercial service.

In the newer designs of tube tanks a valuable improvement has been effected by providing glass windows in the tank covers, this feature affording a full view of the tubes and their connections at all times while in service.

As a further result of these experiments it is hoped that an improved method of cooling the oil in the tube tanks will result in a material reduction in the amount of water required for that purpose in cool climates, and in excessively warm localities that more efficient cooling will be accomplished than is possible with the present forms of this apparatus.

Electrolytic Lightning Arresters

Material improvements are noted in the design and construction of electrolytic arresters, among which are found new arrangements of horn gaps and charging resistances, short-circuiting and transfer devices, and separately mounted fuses, all of which replace earlier forms of equipment. On systems of moderate voltage, fuses are now recommended to serve as cut-outs between the line and horn gaps, and on high voltage systems up to 70,000 volts, as recommended by only one manufacturer, fuses are installed between horn gaps and arrester tanks, in which cases they do not serve as cut-outs for the horn gaps.

In general the use of disconnecting switches with lightning arresters of this type is recommended in order to safeguard operators who are delegated to care for and adjust the apparatus. The Committee is advised that the development of a combined primary fuse and disconnecting switch is in progress, which if satisfactory will be a material improvement over present apparatus.

The advisability of providing barriers or enclosures around lightning arresters, whether installed within doors or outdoors, is definitely recognized, and in addition great care should be exercised to ground all pipe frameworks included in and around arrester installations.

Further experience with the use of an ammeter to accurately determine charging currents makes it evident that its use is to be recommended, as it is of great value in determining the exact condition of the electrolyte.

Choke coils are recommended in some cases for installation with arresters on feeders and where used they are placed on the line side of the disconnecting switches in order to secure the benefit of their protection for the switches.

In the past various arrangements of arresters have been specified by manufacturers for grounded and ungrounded neutral systems, but at present there appears to be a unanimity of opinion in recommending the use of arresters as arranged for non-grounded systems, whether the system is to be grounded or not.

Marked improvement in the electrolyte furnished with arresters is noted and the elimination or prevention of fungus growth appears to have been successfully accomplished. It may further be added that an electrolyte is now available which may be subjected to comparatively low temperatures, 20 deg. fahr. below freezing, without materially affecting its efficiency. This will undoubtedly permit the use of electrolytic arresters in many locations not previously convenient for their installation.

There is still a great diversity of opinion among engineers regarding the advisability of using arresters of this type, some preferring to be without protection rather than use them, while others feel that a substantial measure of protection is afforded by their use. In view of the many changes in design and construction that are continually being effected in this apparatus, the Committee is not preparad to make definite recommendations for its use, but believes that in most cases where its use has been along approved lines, benefits have accrued to the users.

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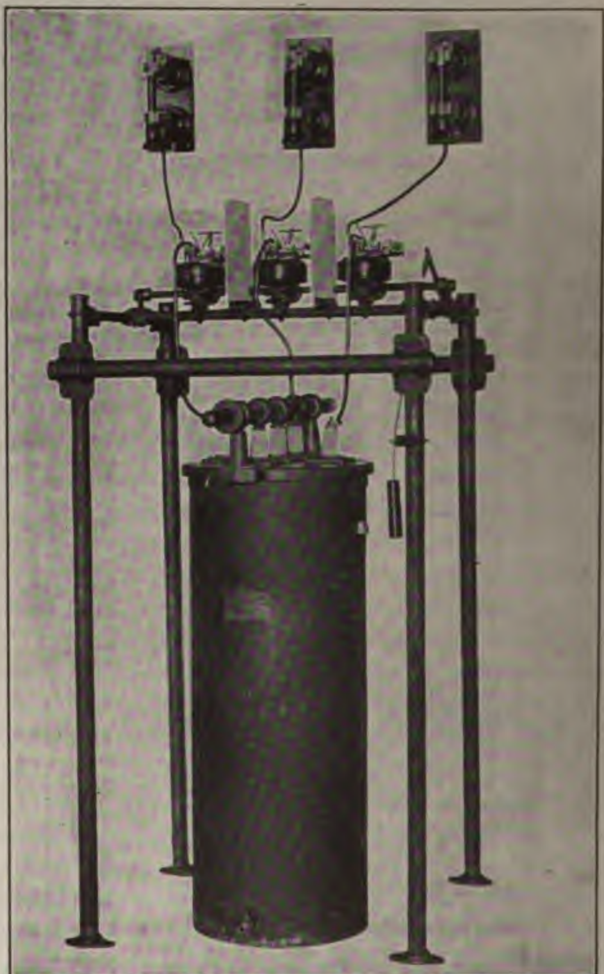


FIG. 14. IMPROVED FORM OF SINGLE-TANK ALUMINUM ARRESTER FOR PRESSURES NOT EXCEEDING 6600 VOLTS

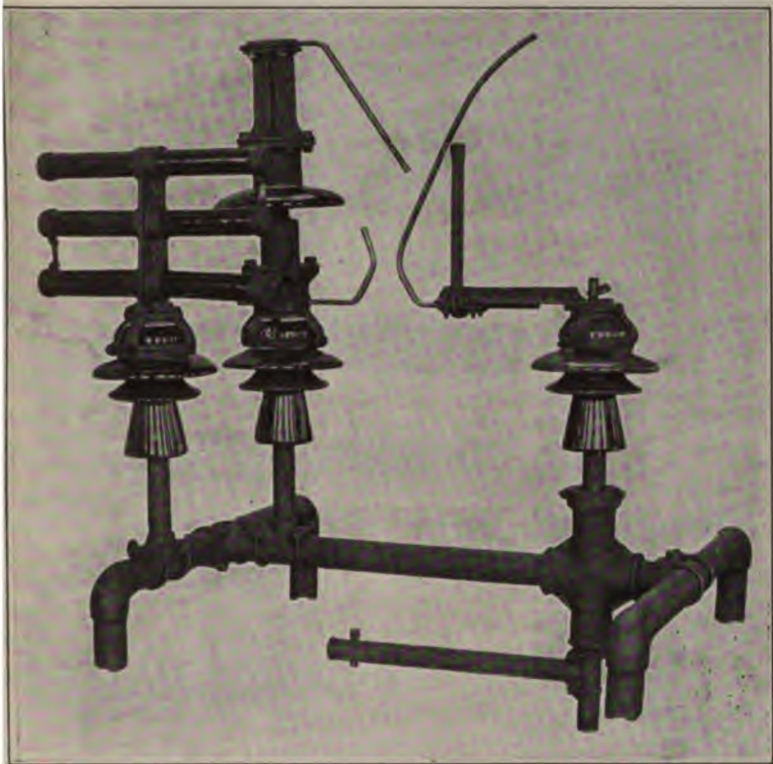
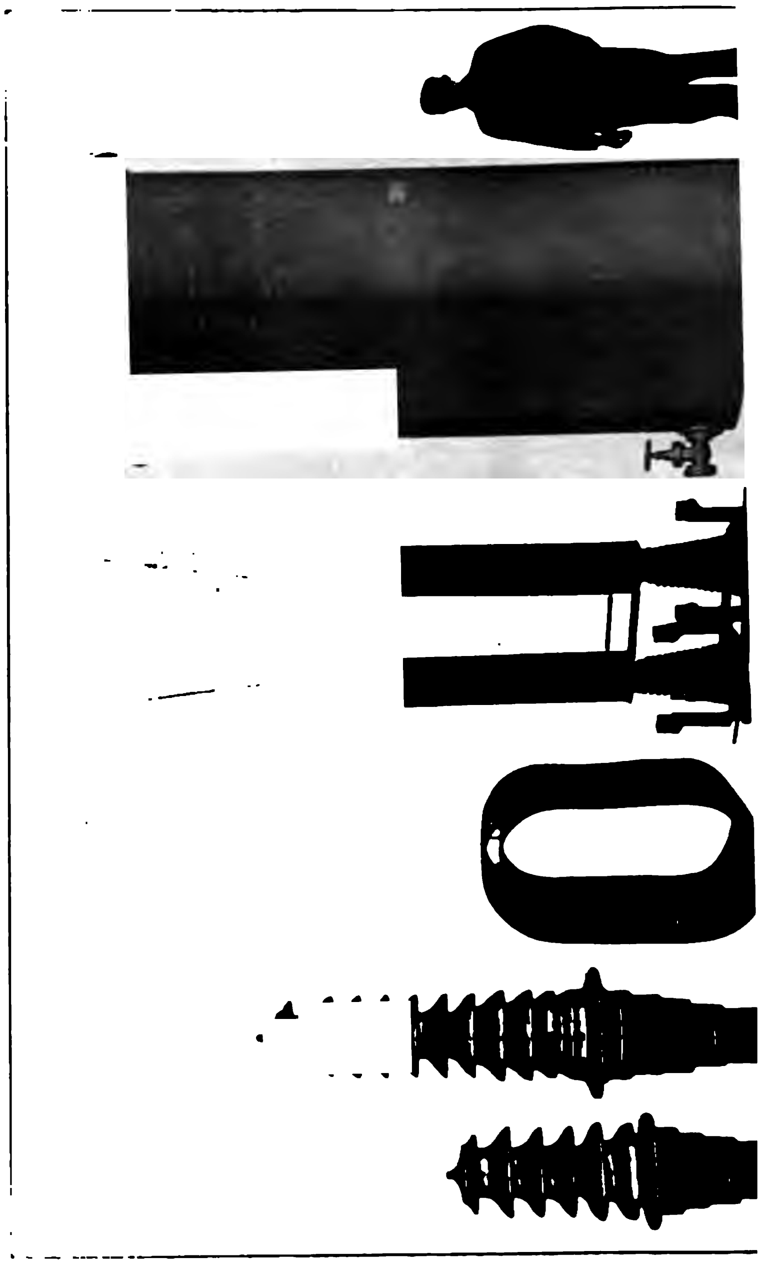


FIG. 15. IMPROVED ARRANGEMENT OF HORN GAPS AND CHARGING RESISTANCE FOR ALUMINUM LIGHTNING ARRESTER



High Potential Testing Apparatus

Increasing interest in this class of apparatus is apparent from the many inquiries directed to manufacturers and users of such equipment. A number of member companies have ordered or are preparing to order testing equipments of larger capacities suitable for use in testing underground cables and station apparatus. Reports from those companies that regularly carry out high potential tests on their apparatus would seem to show that its use was fully justified in searching for defects in advance of failure of apparatus.

The specific design of such apparatus varies, but for general work requiring small capacities, 60-cycle testing outfits offer the best propositions. For capacities requiring in the neighborhood of 1000 kilovolt-amperes, single-phase at 60 cycles, it may be desirable in order to obtain the benefit of the cost of small capacity apparatus to go to 25 cycles, as the transformers and reactances can then be of capacities in the ratio of 25 to 60. Sixty-cycle testing outfits, however, offer a more rigid test of voltages applied for the same length of time, as the maximum number of voltage points in 60-cycle apparatus over 25-cycle apparatus will also be in the proportion of 60 to 25.

The use of frequency lower than 25 cycles has been considered, but because of the small number of maximum voltage points in the given time, and also the large increase in cost, especially as regards the generator, it has been deemed inadvisable to use frequencies below 25 cycles.

Tests have shown that the best transformers can be designed with taps for various voltages in the low tension winding, but that the high tension winding should in all cases be supplied without taps, and there should of course be no high tension switching. Testing transformers are supplied with a voltmeter coil wound on the core in such a position as to be affected by the same flux as the high tension winding, as this has been found to be the most accurate method of reading the high tension voltages.

For testing 3-conductor cables on 3-phase transmission lines it is sometimes advisable to use 3-phase generators, testing transformers and reactances in order to reduce the number of tests necessary to determine a weak spot in the line. This saving in time, however, does not always warrant the increase in cost of 3-phase over single-phase apparatus and the most common testing outfits are for single-phase work only.

Considering either the 3-phase or single-phase apparatus we have a number of alternatives from which to make our choice.

(1) An induction regulator and testing transformer with low tension winding designed to operate in connection with the regulator from supply bus-bars. This is not recommended, as the system may vary considerably from a true sine wave and in addition to this the induction regulator for large values of leading or lagging current adds considerably to this distortion.

(2) A motor-generator set with sine wave generator, designed for the full capacity of the charging current in the line and all losses of the testing apparatus. With this would be used a testing transformer of the same capacity.

(3) A motor-generator set with sine wave generator of capacity only sufficient to supply the losses, a transformer of full capacity as in (2), and a shunt reactance in the low tension circuit of the transformer sufficient to balance the leading current taken by the cable under test and thus allow the generator to run at nearly unity power-factor, a condition favorable to good wave shape. This also helps in maintaining regulation.

(4) A motor-generator set with sine wave generator with capacity to supply the losses, a transformer of the same size and a reactance of the same capacity as in (3), connected in the high tension circuit of the transformer.

(5) Similar to (4), with the exception that the reactance will be variable instead of constant.

(6) A motor-generator set with sine wave generator large enough to supply the losses and a transformer of the same capacity as in (3), with a gap in the core to provide the necessary shunt reactance, or in other words a large exciting current.

Of these, the full capacity generator and transformer will be the most expensive, and the cost of the others is in the order in which they are listed. The cost of the regulator and transformer for use on the system will depend upon the frequency.

As there is no way of changing the reactance of the equipment in (2), the generator will be subjected to heavy leading and lagging currents, and consequently, even though the generator be specially designed, the deviation from a true sine wave may be in the neighborhood of between 15 and 20 per cent.

For low voltage work—that is, testing at voltages of 30,000 or below, (4) is superior to (3). For higher voltages than this

it is difficult to design reactances for the high tension side, and (3) should be used in preference to (4) or (5).

In (4), for capacities up to approximately one-half the total capacity, the transformer would be used without the reactance and the reactance would be in circuit for testing lines requiring capacities between one-half normal and normal.

In (5) the variable reactance which is usually limited to small sizes should be provided with a movable core and the reactance kept in circuit with the transformer for all loads, the variations being made according to conditions of test.

On (6) the shunt reactance is fixed, so that the power-factor of the load on the generator will vary with the length of cable to be tested, which will cause a considerable variation in wave shape and effective voltage. It is believed that the variation will be between allowable limits. The reactance could be varied by adjusting the air-gap, but in the case of a large transformer this would introduce a complicated and expensive mechanical design on account of the large magnetic forces to be balanced.

Testing with high voltage, direct current has been considered, but enough experimental work has not yet been carried on to determine its advantages and disadvantages as regards the apparatus or its effect on a cable under test. It, however, offers the possibility of low capacity testing apparatus irrespective of the length of a tested cable, but, on the other hand, it offers a constant voltage instead of a large number of maximum voltage points per second, thereby materially reducing the severity of a test when compared with a test with alternating-current potential of equal value for the same period.

Efforts to obtain high direct-current voltage through the use of a number of high voltage direct-current generators in series, or by using high voltage mercury arc rectifiers similarly connected, have not been successful, so that the development of direct-current testing facilities for high voltage work is still in the future.

Reference has been made to the provision of a special winding on testing transformers for use in measuring the testing potential in place of using an auxiliary potential transformer on spark-gaps.

The needle spark-gap is not accurate and as at present used furnishes only a rough check on the voltage. The voltage as measured by spark-gap may vary from the following causes:

Variation in wave form

Transient voltage generated by unstable conditions of test circuit

Ionization of air.

The spark gap is proportional to the maximum value of the potential wave and thus depends upon the variation of wave shape when compared with the voltage read from a voltmeter coil on the transformer, which is the most accurate method of measuring the mean effective voltage.

The resistance generally used in series with spark-gap in most tests varies from one to five ohms per volt—that is, it will allow from one-fifth to one ampere of current across the spark-gap. The higher value of current is used with a large testing transformer. For instance, a 500-kilovolt-ampere testing transformer could stand one ampere at 500,000 volts without overloading. It is preferable to use water-tube resistance as being more reliable than carbon rods, on account of the coherer action of the latter and also of their wide variation in resistance.

The use of sphere spark-gaps will probably be recommended to the Institute as more accurate than the needle-gap. The sparking distances with spheres are smaller than with needle-gaps but the method is accurate and reliable only within a certain range for each size of sphere—that is, a range in which the distance between the surface of spheres is not over three times the radius. Thus for 300 kilovolts it becomes necessary to use a sphere approximately 25 cm. or 10 in. diameter, the sparking distances between surfaces for such spheres being about 31 cm. (12.2 in. for 300 kilovolts). A 2.54 cm. (1 in. sphere) gives reliable results up to 60,000 to 80,000 volts. The sparking distance when spheres are used is less than needle-gaps unless small spheres are used for large gaps and high voltages, in which case the breakdown voltages are affected by corona and the readings depart from the regular curve.

DISCUSSION

Mr. Moultrop: Without appearing to be criticising my distinguished colleague who has just submitted this report, I am disappointed that he did not emphasize one feature more strongly, that relating to the noise from running machinery. We

are having a great deal of trouble with that in Boston, and I know that other large companies are having some trouble. In the olden days when we had only one or two stations, and they were in sections of the town or city where noise was not objectionable, we paid no attention to this thing; but as the business grew we have put sub-stations in suburban and residence sections, and in other places where quiet is imperative, and we are finding it very difficult to operate the present apparatus and keep the neighbors happy.

This is a subject that we have been discussing with the manufacturers at considerable length for some time, and I do not get much satisfaction from them. They tell me the solution is to box the station up and have artificial lighting, forced ventilation, and all that sort of thing. That may be the solution, but I hate to think that we are going to make jails out of our sub-stations and have our operators work in them. It does seem to me that there might be some effort made towards giving us at low cost the same efficient rotating machinery that we are getting to-day, and still have it reasonably quiet in action. I do not think the expedient of entirely enclosing our stations is altogether happy. We have tried that in one of our stations located in a sub-basement, where the only connection with the outside is through ventilating flues 30 to 50 feet in length, and when the majority of our apparatus is running in that station there is so much noise that the operator cannot use the telephone even with the use of the approved sound-proof booth. I trust there will be something more brought out on this subject during the morning.

MR. R. F. SCHUCHARDT, Chicago: As usual, the report of this committee is full of good meat and splendidly arranged. It is, therefore, of considerable value to the members, and really but very little can be added to it.

Mr. Insull stated last night that our visitors could find a few things of interest and value in Chicago, and it has occurred to me that reference to some of the things in our operating system that are referred to in the report might be of interest.

The 30,000-kw. machine that Mr. Abbott referred to is a 1500-revolution machine, the output of which is to be controlled by electrically operated switches similar to those the delegates have seen in the Northwest Station. These are now operated on

the 20,000-kw. units, and with the special arrangements included in their design based on the tests made at the Fisk Street station three years ago, have given us considerable confidence in their proper action. This 30,000-kw. machine will be a 9000-volt unit, differing in that respect from the two machines at the Northwest Station.

With reference to proper amounts of reactance I do not entirely agree with the statement on page 498, that the percentages recommended should be accepted without qualification. What we are interested in is limiting the amount of energy available and delivering it at such a point that we can handle it properly with a switch. The limit of 60,000-kw. capacity, as the limit which it is desirable to have on any one section of the system, refers to the Chicago system, and that limit was placed at a time before we had current-limiting reactances. Up to the present time we have, of course, had no occasion to change this limit. We are still operating within it, but it is very probable that the addition of these larger units; and the rearrangement which will come incident to that, will make it necessary and very desirable to increase that limit. How high it will be made we are not prepared to say; probably somewhere near 100,000 kilowatt, but the change indicates at least a step in advance.

With reference to the request to the manufacturers that they pay special attention in these high-speed sub-stations to making generating machinery noiseless, it may be interesting to know that in one of our sub-stations, a 60-cycle distributing sub-station, where we had frequency changers installed, we have replaced the frequency changers with transformers, putting them on our 60-cycle generating system. In this particular instance the sub-station is in a very high-class residence district. The nearest house is about 300 feet from the sub-station, and to keep the neighbors happy, we cut out the noise made by the 300 rev. per min. frequency changers.

Mr. Elden has referred to the fact that we are about to adopt what we have called a simplified scheme of excitation. In addition to having an exciter on the shaft, we are going to take what is perhaps a very bold step—that of running the exciter directly connected to the slip rings of the generator field, with no emergency control whatever. That means that while we are still to have all necessary connections to throw

over, and can put these in if we find it absolutely necessary, we hope they will not be needed. The manufacturers are paying special attention to this exciter, which is to be as rugged and reliable as it can be made, and we think the experiment will result satisfactorily. If something happens to the exciter, the probability is that the unit must be shut down anyway, because part of the exciter is right on the revolving section of the machine.

MR. PHILIP TORCHIO, New York City: The report calls attention to the efforts the American Institute of Electrical Engineers is making to revise its rating of electrical apparatus, and it might perhaps be opportune to make a statement concerning that. I want to call special attention to the importance of the situation, although it is one with which every user of electrical apparatus is familiar. Within the next few months some decision is to be made, and the result of this on their business and the interests of their customers should be known before this decision is announced.

The percentage of reactance for the bus-bar recommended in the report should, I think, be revised by making it for the full capacity of the switch between the sections, instead of for one-quarter or one-third such capacity. In such cases, the recommended reactance instead of being 20 to 33 per cent, might be reduced to 7 to 12 per cent. It would amount to the same thing, but states in more definite form what it should be. I want to add that the reactance needed between generating stations is also essentially as much as between sectional bus bars, and to emphasize this view when you add different generating stations to run in parallel, that the maximum synchronizing power interchanged between two stations is obtained with a ratio of the reactance to the resistance of the circuit of 1:1.73.

Reactances

MR. PAUL M. LINCOLN, Pittsburgh, Pa. (submitted in writing):

Class No. 3 refers to reactances for the purpose of limiting currents. This paragraph states that economy dictates the use of reactances without iron cores for this purpose. Under certain conditions it is quite possible that iron core may be lower in cost than air-core reactances, and for such conditions iron

tiated from the air-blast type, and the writer would suggest a change in the phraseology of this sentence.

Reference is made to failures in transformers and switches, due to the collection of moisture at terminals, owing to temperature variations. The elimination of this trouble is entirely a question of good design and care in operation, and with proper attention and modern apparatus there should be no trouble from moisture collecting inside of transformers or switches.

The lack of a suitable outdoor aluminum cell lightning arrester is mentioned and it may not be amiss to call attention to the fact that the aluminum cell lightning arresters used by the Westinghouse Co. are designed to be installed outdoors and are recommended for such use. It really seems unnecessary to develop a non-freezing electrolyte, since, as is well known, lightning disturbances and cold weather do not occur simultaneously.

I wish to endorse with all possible emphasis the recommendation that all metering be done on the low-tension side of outdoor transformers.

MR. ERIC A. LOF, Schenectady, N. Y.: I would like to say a few words in regard to exciter systems. Evidently the reference in the report is to steam stations, because it seems to be the general opinion that in a small station where you have two or three units it does not work out so well. In such cases it is the general practise to make the capacity of the exciters large enough to excite two generators, and in case of trouble one exciter can be disconnected, and use can be made of that generator. For a large station it is very general to use three exciters, two for normal operation and the third one for a reserve. The latest practise also is to let the exciters be regulated with a constant voltage. The voltage for the alternators can then be regulated by means of a booster and regulator, so that exciter current can be used for station purposes.

MR. E. P. DILLON, Pittsburgh, Pa.: There is one point on the subject of reactance, as covered in specification C, page 500, that, I think, should be emphasized a little, and that is the use of reactance on feeders, not individual feeders only, but where parallel feeders are used. This point is valuable in assisting to maintain full voltage on the bus bars, so as to prevent the dropping out of synchronous apparatus on other feeders until such time as the circuit breaker is able to open.

Under the subject of rotary converters on page 16, the statement is made with reference to the newer machines, that these are usually made of either the synchronous booster or split-pole type. Referring to variable voltage rotary converters which are used at the present time to a very large extent on lighting systems, such machines are not generally applied to railway work. I simply want to call attention to an apparent misstatement there.

It is also interesting to note the increase in the sizes of 60-cycle rotary converters within a very few years. Probably five years ago there were very few 1000-kw. converters in service, in one instance only, some 2000-kw. converters. However, since that time the 1000-kw. 60-cycle rotary converter is being very generally applied to railway systems. At the present time there are a number of 2000-kw. modern converters in service, and it is safe to say that the end is not yet. It is simply a question of the demand as to the size of the units that may be built.

MR. J. E. KEARNS, Schenectady, N. Y.: I am very much interested in the statement made by Mr. Moultrop regarding the noisy operation of electrical machinery. I think it was probably prompted by the results obtained from machines that were not specially designed for quiet operation. The necessity of installing electrical machines for quiet operation is increasing rapidly, due, principally, to the congested growth of our larger cities, necessitating the installation of the machines in the basements of buildings. To meet these conditions manufacturing companies are, at the present time, building several units designed for quiet operation. It should be borne in mind, however, that machines to operate noiselessly must be designed for very low speeds and so totally enclosed as to make forced air ventilation necessary, with the result that machines so designed are bound to be quite expensive.

Another important subject in this report that has not been discussed is the motor converter. I understand that Mr. Arthur Wright, of England, is at the conference, and may be in a position to give us some interesting information.

On page 513 of the Report there is a table outlining a comparison of motor converters with rotaries and motor-generator sets. By referring to this table it will be noted that the efficiency of the motor converter is given as within one per cent of that of

design of a special combined fuse and disconnecting switch, or that such a piece of apparatus would be any improvement over present practise.

The use of a special ammeter for determining the charging current does not seem to us at all necessary, and as such an ammeter cannot be used for any other purpose, it would seem to be an added complication and expense to the user. Daily or frequent use of the ammeter is unnecessary in determining the condition of the arrester, while a test by ammeter two or three times a year can be made with comparatively little trouble by the use of any standard portable or switchboard type of meter which may be available, by connecting it in the circuit. The appearance of the arc on the horn gaps is ordinarily an ample guide to the condition of the arrester. On the other hand an ammeter indication is not always accurate, as the charging current is affected by line voltage, frequency, wave form, temperature, presence of harmonics, etc.

We still recommend the use of grounded neutral arresters wherever the neutral is grounded through a resistance (if any) low enough to insure the circuit breakers tripping if a ground occur on any phase. When grounded neutral arresters are used properly they afford better protection than would ungrounded neutral arresters, owing to the lesser number of trays between any phase and ground.

We have succeeded in eliminating the condition of fungus growth from the electrolyte, since 1909 in part of our electrolyte, and since 1910 in all of it. This is due to the use of an inorganic electrolyte, the latest form of which has, for the past two years, been extremely successful.

On page 529, under the subject of Relays, reference is made to an induction-type relay, which is claimed to be satisfactory for alternating-current and reverse power work, but the Committee disclaims knowledge of its actual operation. I can state that we have approximately 250 of these relays giving satisfactory service in a large number of places.

Mr. A. D. Fishel, East Pittsburgh, Pa. (submitted in writing):

In connection with the speed of operation of automatic feeder regulators, it has been our experience that the apparent advantages of very high speed in the regulator mechanism are usually

counteracted by relative disadvantages and that a practical compromise is usually desirable.

Reliability of operation is an important feature of an automatic feeder regulator. This seems to be inherently best obtained with the induction type of regulating equipment. With the use of modern auxiliary apparatus for automatic control, the induction type lends itself to speeds of operation which have been proved sufficiently high to fully take care of practically all of the normal central-station requirements. With the present high-grade central station practise of laying out distributing systems, feeders are rarely subjected to very rapid voltage fluctuations of more than a few per cent of the total, but the important sphere of the automatic feeder regulator is to take care of the many small voltage fluctuations, to correct them quickly and to maintain close voltage regulation.

Offhand, it would seem that the higher the speed, the more satisfactory the regulation, but experience has shown that modifying factors are: (1) the limitations of the auxiliary devices necessary; (2) the detrimental effect of too high a speed upon the apparatus; (3) that very high speeds, with close voltage settings, may require more careful inspection as well as a greater amount of attention from capable station attendants.

Developments in the past two years have been to provide auxiliary equipment which would permit very quick starting and stopping of the control and operating mechanism, so that full advantage could be obtained of the induction type of regulator together with quick correction of voltage fluctuations. In one group of equipment, the operating motor of the induction regulator is brought up to normal speed in less than three-tenths of one second after the primary relay or contact-making voltmeter acts, and when the voltage is brought to normal the regulator is stopped within one-tenth of one second. This is accomplished by rapid and positive auxiliary relays with quick-acting magnetic brakes for the motor.

With such equipment available, further increase in the speed of operation only of the regulator from the position of maximum buck to the position of maximum boost will not result in an improvement in regulation sufficient to warrant the use of the extremely high speeds obtained with other than the induction type of equipment, with their resultant greater depreciation and higher

maintenance. In both types of equipment, a fair percentage of the time necessary to correct the small voltage fluctuations is consumed in the operation of the primary and auxiliary relays or clutches, so that considerable difference in the speed of the regulator produces only a small difference in the total time required to bring the voltage to normal. For the average central-station feeder, consisting of lighting load with a fair proportion of motor load, a speed of about sixteen seconds from the position of maximum buck to the position of maximum boost has been found by experience and tests to give most satisfactory results. Where fluctuations are more severe and very close regulation not so essential, a speed of about ten seconds for the complete range has proved to be very satisfactory.

High-Potential Testing Apparatus

The report on the high-potential testing apparatus is of considerable interest in connection with the increasing amount of high-voltage testing in the field, as well as better standardization of the large amount of high voltage testing now necessary in the factory to produce transformers, circuit-breakers, insulators, bushings, etc., that will have proper factors of safety, and also to conform to definite tests that may be specified.

In connection with alternative No. 1 of the testing outfits, it frequently happens that a motor-generator set is not available, or its installation not practicable. It has been found that regulating transformers provided with suitable dials or drums equipped with preventive resistances to prevent the opening of the circuit, form a very satisfactory method of varying the testing voltage when it is obtained from a constant supply. Another method, which overcomes, to a large extent, the objections to the use of the induction regulator as distorting the wave form, is to use a regulating transformer with a regulating dial or drum to provide a number of large steps of voltage regulation and then have one small induction regulator to give the smooth voltage regulation between each step of the regulating transformer. With this method, the capacity of the induction regulator is only a relatively small percentage of the transformer capacity. The induction regulator is motor operated and its operating switch is geared to the regulating drum so that the regulator is automatically transferred from one step to another,

and provides a smooth voltage variation through the complete range of the regulating transformer.

With the present status of high-voltage work, it is necessary that applied tests and measurements be uniform and accurate. The use of a special winding in the testing transformer in connection with a voltmeter is a practical method of reading the high-tension voltage, but is not very accurate. It is impossible to have all of the flux that passes through the high-tension winding of a high-voltage transformer pass through the voltmeter coil, so that there is an error in this method of measurement of the high-tension voltage, even when effective values are suitable. Of course, the maximum value of the voltage is the essential feature in connection with high-voltage testing, and this maximum value changes with the wave form, so that measurement of the effective value by means of such a voltmeter coil does not take into account the maximum value of the voltage or the high-frequency oscillations which may occur, and further, does not protect the apparatus under test from such oscillations. It is the maximum voltage which is concerned in measuring the rupture strength of insulating material, and, therefore, the use of a voltmeter coil as an index thereof, is not a very reliable means of measurement.

This necessity for accurate measurement brings us to the use of the sphere spark gap which has recently been thoroughly tested in service and well standardized, and which is recommended in the Committee's Report. A few points on this sphere gap may be of interest.

The breakdown strength of air is constant under any given set of terminal conditions and with constant pressure, temperature and humidity conditions. To properly apply this characteristic, there must be available definite standards which will consistently show when the air reaches a breakdown point and which can be determined by something positive, such as a spark or a sharp cracking noise instead of by visual corona, which is not quite as reliable. Such a standard must have its intensity increased progressively, so that a sharp break will occur at the breakdown point. The sphere spark gap has been found to conform to these requirements because its shape can be definitely determined, because a sphere is less subject to change than any other shape and its characteristic can be better and more easily

specified. The only irregular feature is the shank, whose size and shape can be readily specified, and, further, the shank is farthest removed from the breaking point.

The sphere gap lends itself to a suitable mechanical construction in a vertical position. In this construction the upper sphere is stationary, while the lower sphere is provided with a micrometer adjustment. This outfit is readily made portable, occupies little floor space, the parts can easily be kept in constant alignment, and the necessity for repeated zero adjustments is eliminated.

With the sphere spark gap used in testing, it is first set for the testing voltage until a flash-over is obtained, then it is reset for 15 or 20 per cent above this. Then, if oscillations should be set up in the high-voltage circuit, the spark gap relieves the surges and opens the circuit so that the apparatus is fully protected.

Calibration curves for these spark gaps of the standard sizes, such as those of 25, 37½ and 50-cm. diameters can be obtained by direct means, show the maximum value of the e.m.f. wave, and are accurate within two per cent after the slight corrections are made for atmospheric pressure and temperature conditions, the rupturing point of air varying directly with the pressure and inversely with the absolute temperature. For ordinary commercial testing this correction for pressure and temperature is so small that it can be neglected.

The sphere gap can be used with high accuracy and over a great range, starting with about 30,000 volts. The sphere of 12½-cm. diameter can be used up to 150,000 volts effective value; 25 cm. to 275,000 volts; 37½ cm. to 412,500 volts, and the 50 cm. to 550,000 volts. These figures apply where the spark gaps are used with testing equipments in which one side is grounded, this having been found to be a very reliable method of furnishing high-voltage equipment. If the middle point of the testing outfit is grounded, it is best to use two sphere gaps or next best, to use one sphere gap between one high-tension side and ground, and then double this voltage. When the middle point of the testing transformer is grounded, and an ungrounded sphere gap is used to measure the voltage between terminals, the measurements are more subject to variation due to the influence of neighboring fields or bodies. The sphere spark gap has

been calibrated by an absolute method and found to very uniform over a wide range of frequency. These gaps have been tried in commercial as well as laboratory practise for some time and have proved very satisfactory as absolute measurements, always giving consistent results, as well as providing protection to the apparatus under test.

With regard to the resistance, we have found about one-half to one ohm per volt desirable. Water-tube resistances have been considered dangerous to some extent, because of their tendency to explode and scatter flying particles of glass.

MR. T. J. PACE, Pittsburgh (submitted in writing):

On page 530, under Rectifiers, the first two sentences seem to confuse mechanical with electrical trouble. Like all other economically designed apparatus, rectifiers will give rise to operating difficulties when abused, but the present commercial types may be considered free from mechanical failures, except under conditions where unusually severe circuit disturbances occur.

The present high-tension rectifier bulb will give a life in the neighborhood of 1000 hours on the average, and on this basis, allowing three minutes to replace a bulb, it will be evident that a maximum delay for an entire year, due to bulb renewal, will be quite negligible. Insofar as momentary interruptions, as referred to in the report are concerned, these would not prove annoying, should the outfit be provided with the so-called condenser, it being assumed, of course, that the oil around the bulb is within the prescribed temperature limits.

The development of various devices to shift the load from one bulb to another in case of failure, as well as the attempts which, it is reported, are being made to operate a number of bulbs in series, should not be taken as an indication that rectifier performance has not reached a satisfactory commercial standard. There are too many rectifiers of the single-bulb type carrying 50 lamps or less in satisfactory service to warrant any such assumption. It would, however, have been very interesting to have included in this report some definite data, covering a reasonably long operating period, with reference to the bulb life secured under similar operating conditions with equipments of one and two bulbs, respectively; also what effect a bulb suddenly dropping out of service may have on the remaining bulb.

In connection with the experiments reported to be under way on an improved method of cooling the oil and thereby reducing the amount of water required for this purpose, it should be kept in mind that, except in the case of unusually large rectifier outfits, the use of water for cooling purposes is not an absolute necessity, as exemplified in certain available designs.

In solving the problem of supplying a device without rotating or vibrating parts for commercially rectifying high-voltage alternating-current, some obstacles of unusual difficulty have been successfully overcome, and in a manner which results in a piece of electrical apparatus which is by no means experimental.

The comprehensiveness of this report with particular reference to the number of subjects treated necessarily made it quite impracticable for the Committee to dwell in detail upon any one subject. The Report, as a whole, evidences considerable study and time on the part of the Committee, which, I believe, should be congratulated on the very excellent work it has performed.

Mr. Charles G. Durfee, Rochester, N. Y.: I would like to state for the Committee on Meters, that it has done some work during the past year with reference to a standard method of bringing out the leads on current transformers with reference to testing meters located in various stations; also with reference to getting some standard method of making up connection diagrams. We find that manufacturers have various ideas on the subject of connection diagrams and they do not agree with each other, so that it is difficult sometimes for the metermen to read these diagrams correctly. It has occurred to your Committee on meters that it might be a very good idea if this Committee and the Meter Committee should co-operate to the extent of having joint meetings during the coming year.

The Chairman: That is a matter for discussion.

Mr. Elden: In reply to the suggestion of Mr. Pace on the duration of interruptions to bulb replacements as well as for momentary interruptions, it would seem that the interruptions which are experienced for the reasons given are sufficiently serious to be considered unsatisfactory for commercial conditions where continuous service is the ultimate object of the supply company. It may be stated that a number of representative installations using all the commercial forms on rectifying equipment report many interruptions of the above character, regardless of the number of tubes

mployed in each case, and it would, therefore, appear that im-rovements in the apparatus are desirable to eliminate these bjectionable features.

Another matter as to reactances. When considering bus re-ctances and the desirable amount of reactance which should be ncluded in their design, attention is directed to the statement n page 500 of the practise of one manufacturing company, where t is recommended that 20 to 33 per cent reactance be employed n such locations. There values are considered to be excessive, nd, in fact, prohibitive in some cases, which fact emphasizes the importance of studying each situation before deciding the actual percentage of reactance for each location.

On behalf of the Committee, I wish to thank the Chairman and those who have taken part in the discussion, for the very ample, full and free discussion which has been given to the report.

THE CHAIRMAN: The next Report is that of the Joint Committee on Overhead Line Construction. Unfortunately, the Chairman, Mr. Farley Osgood, is not here, but Mr. F. B. H. Paine, of Buffalo, will submit the report for him, as he is one of the members of the Committee.

REPORT OF THE JOINT COMMITTEE ON OVERHEAD LINE CONSTRUCTION

The Committee has held several meetings during the past year, holding its closing meeting at the Association Headquarters on May 7 and 8, when all suggested changes which have been brought to the attention of the Committee were discussed in detail. Final action as to recommendation for changes in the report resulted in a number of changes which simplified the wording of the report in several instances, making it easier of clear interpretation.

It was decided to re-write the report, including the suggested changes, and the following report has been prepared. The Committee asks that the Association adopt the Specification in its present form, to bring the National Electric Light Association up to date with the Committee in its recommendation of standards.

To facilitate comparison a star has been placed against any paragraph which has had alteration or addition made to it.

On account of many questions pertaining to construction requirements where conflicting lines do not actually cross but are in close proximity with each other, the Committee recommends that the Crossing Specification be supplemented by other specifications covering required construction for constant potential lines of over 5000 volts, necessarily constructed parallel or in close proximity with lines of telephone or telegraph wires.

It is the opinion of the Committee that the specifications applying to situations of this kind should cover a grade of construction for the power line not less in mechanical and electrical strength than that covered in the crossing specifications.

The Committee feels that on account of the great amount of attention given to this specification work by other Associations at interest, it is desirable to broaden the scope of the Overhead Line Construction Committee and to change the title to the "National Joint Committee on Overhead Line Construction," thus eliminating any one Society as the sponsor for the Committee, and making the organization of the Committee sufficiently strong and of such general personnel as to cover all the require-

ments for overhead line construction work, and to cover them on a completely mutual basis.

It is felt that if this can be accomplished, various branches of line work can be handled by subcommittees of this general National Joint Committee, and that no conflicting specifications would be likely to result from such a community of interest in the National Joint Committee.

There has not been time to prepare for this Convention a distinct plan of creation for this National Joint Committee, but your Committee asks the authority of the Association to formulate a National Joint Committee as suggested in any way which may seem best, which method shall carry the approval of the Executive Committee of the National Electric Light Association before final action on the part of your representatives is taken.

We cannot urge too strongly the necessity of such action and the great amount of good that can come from a National Joint Committee as described, and tentative discussions with the representatives of our sister Associations lead us to state here that this plan will unquestionably receive general approval, as not only feasible but most desirable of accomplishment.

Respectfully submitted,

Committee
FARLEY OSGOOD, *Chairman*
F. B. H. PAINE
PAUL SPENCER
F. L. RHODES
PERCY H. THOMAS
HARRY M. HOPE
R. D. COOMBS
THOMAS SPROULE
W. T. OVIATT
J. F. DOSTAL
GEORGE H. LUKES
A. S. RICHEY
GEORGE A. CELLAR

SPECIFICATIONS FOR OVERHEAD CROSSINGS OF ELECTRIC LIGHT AND POWER LINES

GENERAL REQUIREMENTS

*1 *Scope*: These specifications shall apply to overhead electric light and power line crossings (except trolley contact wires), over railroad rights-of-way, tracks, or lines of wires; and, further these specifications shall apply to overhead electric light and power wires of over 5000 volts constant potential, crossing telephone, telegraph or other similar lines. It is not intended that these specifications shall apply to crossings over individual twisted pair drop wires or other circuits of minor importance where equally effective protection may be secured more economically by other methods of construction.

2 *Location:* The poles, or towers, supporting the crossing span shall preferably be outside the railroad company's right-of-way.

*3 Unusually long crossing spans shall be avoided wherever practicable, and the difference in length of the crossing and adjoining spans generally shall be not more than 50 per cent of the length of the crossing span.

4 The poles, or towers, shall be located as far as practicable from inflammable material or structures.

5 The poles, or towers, supporting the crossing span, and the adjoining span on each side, shall preferably be in a straight line.

6 The wires, or cables, shall cross over telegraph, telephone, and similar wires wherever practicable.

*7 Cradles, or overhead bridges, shall not be used beneath the crossing wires or cables; but in cases where the crossing wires or cables cross beneath the railroad wires, telephone, telegraph or other similar wires, a protection of adequate strength and proper design between the two sets of crossing wires or cables may be required.

*8 Unless physical conditions or municipal requirements prevent, the side clearance shall be not less than 12 ft. from the nearest track rail, except that at sidings a clearance of not less

than 7 ft. may be allowed. At loading sidings sufficient space shall be left for a driveway.

9 The clear headroom shall be not less than 30 ft. above the top of rail under the most unfavorable conditions of temperature and loading. For constant-potential, direct-current circuits, not exceeding 750 volts, when paralleled by trolley contact wires, the clear headroom need not exceed 25 ft.

10 The clearance of alternating-current circuits above any existing wires, under the most unfavorable conditions of temperature and loading, shall be not less than 8 ft. wherever possible. For constant-potential, direct-current circuits not exceeding 750 volts, the minimum clearance above telegraph, telephone and similar wires may be 2 ft. with insulated wires and 4 ft. with bare wires.

*11 The separation of conductors carrying alternating-current, supported by pin insulators, for spans not exceeding 150 ft., shall be not less than:

Line Voltage	Separation
Not exceeding 7,000 volts	12 inches
Exceeding 7,000 but not exceeding 14,000	20 "
" 14,000 " " " 27,000	30 "
" 27,000 " " " 35,000	36 "
" 35,000 " " " 47,000	45 "
" 47,000 " " " 70,000	60 "

NOTE: This requirement does not apply to wires of the same phase or polarity between which there is no difference of potential.

With constant-potential, direct-current circuits not exceeding 750 volts, the minimum spacing shall be 10 in.

For spans exceeding 150 ft. the pin spacing should be increased, depending upon the length of the span and the sag of the conductors.

*12 When supported by insulators of the disc or suspension type, the crossing span and the next adjoining spans shall either be dead-ended at the poles or towers supporting the crossing span, so that at these poles or towers the insulators shall be used as strain insulators; or the height of the wire attachments shall be such that with the maximum sag in the crossing span occurring from failure of the construction outside the crossing span, and taking into account the deflections in the strings of suspension insulators, the minimum clearances, as given in Paragraphs Nos. 9 and 10, shall be maintained.

*13 The clearance in any direction between the conductors nearest the pole or tower, and the pole or tower, shall be not less than:

Line Voltage	Clearances
Not exceeding 10,000 volts	9 inches
Exceeding 10,000 but not exceeding 14,000	12 "
" 14,000 " " " 27,000	15 "
" 27,000 " " " 35,000	18 "
" 35,000 " " " 47,000	21 "
" 47,000 " " " 70,000	24 "

*14 *Conductors:* The normal mechanical tension in the conductors generally shall be the same in the crossing span and in the adjoining span on each side.

*15 The conductors shall not be spliced in the crossing span nor in the adjoining span on either side.

Taps to conductors in the crossing span are generally objectionable, and should not be made unless necessary.

*16 The ties or devices for supporting the conductors at the poles or towers, shall be such as to hold the wires, under maximum loading, to the supporting structures, in case of shattered insulators, or wires broken or burned at an insulator, without allowing an amount of slip which would materially reduce the clearances specified in Paragraphs Nos. 9 and 10.

*17 Ground wires when installed as protection against lightning, shall be thoroughly grounded at each of the crossing supports. In case of their installation on steel supporting structures, they may be clamped thereto. In case they are installed on wooden structures, the ground wire shall be grounded at each of the structures with a solid copper wire, with as few bends as possible and no sharp bends, and not less than No. 4 B. & S. gauge or equivalent copper section. The ground wire itself in the crossing span and the adjacent spans, may be of the same material as the conductors, or a steel strand not less than 5/16-in. in diameter may be used, double galvanized, and having a breaking strength of not less than 4500 lb. and in general shall follow the minimum factors of safety, as provided for the rest of the crossing construction.

If cross-arms are grounded, the same ground wire may be used for grounding the lightning protection wire as in grounding cross-arm strips.

*18 Where there is an upward stress at the point of conductor attachment, the attachment shall be of such type as to properly hold the conductor in place.

*19 *Guys:* Wooden poles supporting the crossing span shall be side-guyed in both directions, if practicable, and be head-guyed away from the crossing span, and the next adjoining poles shall be head-guyed toward the crossing span. Braces may be used instead of guys.

*20 Strain insulators shall be used in guys from wooden poles, except when the guys are through grounded to permanently damp earth.

The insulators shall be placed not less than 8 ft. from the ground. Strain insulators shall not be used in guying steel poles or structures.

21 *Clearing:* The space around the poles or towers shall be kept free from inflammable material, underbrush and grass.

22 *Signs:* In the case of railroad crossings, if required by the railroad company, warning signs of an approved design shall be placed on all poles and towers located on the railroad company's right-of-way.

23. *Grounding:* For voltages over 5000 volts, wooden cross-arms, if used, shall be provided with a grounded metallic plate on top of the arm, which shall be not less than 1/8 in. in thickness and which shall have a sectional area and conductivity not less than that of the line conductor. Metal pins shall be electrically connected to this ground. Metal poles and metal arms on wooden poles shall be grounded.

*24 The electrical conductivity of the ground conductor shall be adjusted to the short-circuit current capacity of the system at the crossing and shall be not less than that of No. 4 B. & S. gauge copper wire.

25 *Temperature:* In the computation of stresses and clearances, and in erection, provision shall be made for a variation in temperature from minus 20 deg. fahr. to plus 120 deg. fahr. A suitable modification in the temperature requirements shall be made for regions in which the above limits would not fairly represent the extreme range of temperature.

26 *Inspection:* If required by contract, all material and workmanship shall be subject to the inspection of the company crossed; provided that reasonable notice of the intention to make

shop inspection shall be given such company. Defective material shall be rejected and shall be removed and replaced with suitable material.

27 On the completion of the work, all false work, plant and rubbish, incident to the construction, shall be removed promptly and the site left unobstructed and clean.

28 *Drawings:* If required by contract (. . . .) complete sets of general and detail drawings shall be furnished for approval, before any construction is commenced.

LOADS

29 The conductors shall be considered as uniformly loaded throughout their length, with a load equal to the resultant of the dead load *plus* the weight of a layer of ice ½ in. in thickness, and a wind pressure of 8 lb. per sq. ft. in the ice-covered diameter, at a temperature of 0 deg. fahr.

30 The weight of ice shall be assumed as 57 lb. per cu-ft. (.0033 lb. per cu-in.).

*31 Insulators, pins and conductor attachments shall be designed to withstand the mechanical tension in the conductors under the maximum loading with the designed factor of safety.

*32 Sags should be such that the stress on the pin falls within the limits of paragraph No. 31, unless methods be employed to prevent an undue slip in case of pin failure. (See paragraphs Nos. 9, 10 and 16.)

33 The pole or towers shall be designed to withstand, with the designed factor of safety, the combined stresses from their own weight, the wind pressure on the pole or tower, and the above wire loading on the crossing span and the next adjoining span on each side. The wind pressure on the poles or towers shall be assumed at 13 lb. per sq. ft. on the projected area of solid or closed structures, and on 1½ times the projected area of latticed structures.

34 The poles or towers shall also be designed to withstand the loads specified in Paragraph No. 33, combined with the unbalanced tension of:

2	broken wires for poles, or towers, carrying	5 wires or less
3	" " " " " " "	6 to 10 wires
4	" " " " " " "	11 or more wires

35 Cross-arms shall be designed to withstand the loading specified in paragraph No. 33, combined with the unbalanced tension of one wire broken at the pin farthest from the pole.

36 The poles or towers may be permitted a reasonable deflection under the specified loading, provided that such deflection does not reduce the clearances specified in paragraph No. 10 more than 25 per cent or produce stresses in excess of those specified in paragraphs Nos. 69 to 73.

FACTORS OF SAFETY

37 The ultimate unit stress divided by the allowable unit stress shall be not less than the following:

Wire and cables	2
Pins	2
Insulators, conductor attachments, guys	3
Wooden poles and crossarms	6
Structural steel	3
Reinforced concrete poles and crossarms	4
Foundations	2

NOTE: The use of treated wooden poles and crossarms is recommended. The treatment of wooden poles and crossarms should be by thorough impregnation with preservative by either closed or open-tank process. For poles, except in the case of yellow pine, the treatment need not extend higher than a point two feet above the ground line.

38 *Insulators:* Insulators for line voltages of less than 9000 shall not flash over at four times the normal working voltage, under a precipitation of water of 1/5th of an inch per minute, at an inclination of 45 deg. to the axis of the insulator.

39 Each separate part of a built-up insulator, for line voltages over 9000, shall be subjected to the dry flash-over test of that part for five consecutive minutes.

40 Each assembled and cemented insulator shall be subjected to its dry flash-over test for five consecutive minutes.

The dry flash-over test shall be not less than:

Line Voltage	Test Voltage
Exceeding 9,000 but not exceeding 14,000	65,000
" 14,000 " " " 27,000	100,000
" 27,000 " " " 35,000	125,000
" 35,000 " " " 47,000	150,000
" 47,000 " " " 60,000	180,000
" 60,000	3 times line voltage

Each insulator shall further be so designed that, with excessive potential, failure will first occur by flash-over and not by puncture.

41 Each assembled insulator shall be subjected to a wet flash-over test, under a precipitation of water of 1/5th of an

inch per minute, at an inclination of 45 deg. to the axis of the insulator.

The wet flash-over test shall be not less than:

Line Voltage	Test Voltage
Exceeding 9,000 but not exceeding 14,000	40,000
" 14,000 " " " 27,000	60,000
" 27,000 " " " 35,000	80,000
" 35,000 " " " 47,000	100,000
" 47,000 " " " 60,000	120,000
" 60,000	twice line voltage

42 Test voltages above 35,000 volts shall be determined by the A. I. E. E. Standard Spark-Gap Method.

43 Test voltages below 35,000 volts shall be determined by transformer ratio.

MATERIAL

44 *Conductors:* The conductors shall be of copper, aluminum, or other non-corrodible material, except that in unusually long spans, where the required mechanical strength cannot be obtained with the above materials, galvanized or copper-covered steel strand may be used.

45 For voltages not exceeding 750 volts, solid or stranded conductors may be used up to and including No. 4/0 in. size; above No. 4/0 in size stranded conductors shall be used. For voltages exceeding 750 volts, and not exceeding 5000 volts, solid or stranded conductors may be used up to and including No. 2/0 in size; above No. 2/0 in size conductors shall be stranded. For voltages exceeding 5000 volts, all conductors shall be stranded. Aluminum conductors for all voltages and sizes shall be stranded.

The minimum size of conductors shall be as follows:

No. 6 B. & S. gauge copper for voltages not exceeding 5000 volts
No. 4 " " " " " exceeding 5000 volts
No. 1 " " aluminum for all voltages

46 *Insulators:* Insulators shall be of porcelain for voltages exceeding 5000 volts.

*47 For pin-type insulators, there shall be a bearing contact between the pin and the insulator pin-hole up to the level of the top of the tie-wire groove, the purpose being that the pin should directly take the strain imposed upon the insulator.

*48 Strain insulators for guys shall have an ultimate strength of not less than twice that of the guy in which placed. Strain insulators shall be so constructed that the guy wires

holding the insulator in position will interlock in case of the failure of the insulator.

For less than 5000 volts, strain insulators for guys shall not flash over at four times the maximum line voltage under a precipitation of water of 1/5th of an inch per minute, at an inclination of 45 deg. to the axis of the insulator. For voltages of more than 5000 volts, the strain insulator or series of strain insulators shall not fail at the line voltage under the above precipitation conditions.

*49 *Pins:* For voltages of 5000 and over, insulator pins shall be of steel, wrought iron, malleable iron, or other approved metal or alloy, and shall be galvanized or otherwise protected from corrosion. (See paragraph No. 47.)

*50 *Guys:* Guys shall be galvanized or copper-covered stranded steel cable not less than 5/16th of an inch in diameter, or galvanized rolled rods, neither to have an ultimate tensile strength of less than 4500 lbs.

51 Guys to the ground shall connect to a galvanized anchor rod, extending at least one foot above the ground level.

52 The detail of the anchorage shall be definitely shown upon the plans.

*53 *Wooden Poles:* Wooden poles shall be of selected timber, reasonably straight, peeled, free from defects which would decrease their strength or durability, not less than 8 in. in diameter at the top, and meeting the requirements as specified in paragraphs Nos. 19, 33, 34 and 37.

*54 *Concrete:* All concrete and concrete material shall be in accordance with the requirements of the Report of the Joint Committee on Concrete and Reinforced Concrete. This may be found on Page 117, Vol. 39—No. 2, of the February, 1913, Proceedings of the American Society of Civil Engineers.

STRUCTURAL STEEL

55 Structural steel shall be in accordance with the Manufacturers' Standard Specifications.

56 The design and workmanship shall be strictly in accordance with first-class practise.

57 The form of the frame shall be such that the stresses may be computed with reasonable accuracy, or the strength shall be determined by actual test.

58 The sections used shall permit inspection, cleaning and painting, and shall be free from pockets in which water or dirt can collect.

59 The length of a main compression member shall not exceed 180 times its least radius of gyration. The length of a secondary compression member shall not exceed 220 times its least radius of gyration.

60 The minimum thickness of metal in galvanized structures shall be ¼ of an inch for main members and ⅛ of an inch for secondary members. The minimum thickness of painted material shall be ¼ of an inch.

PROTECTIVE COATINGS

61 All structural steel shall be thoroughly cleaned at the shop and be galvanized, or given one coat of approved paint.

62 *Painted Material:* All contact surfaces shall be given one coat of paint before assembling.

All painted structural steel shall be given two field coats of an approved paint.

The surface of the metal shall be thoroughly cleaned of all dirt, grease, scale, etc., before painting, and no painting shall be done in freezing or rainy weather.

*63 *Galvanized Material:* Galvanized material shall be in accordance with the Specifications for Galvanizing Iron and Steel (Appendix).

Bolt holes in galvanized material shall be made before galvanizing. Sherradizing for small parts is permissible.

FOUNDATIONS

*64 The foundations for steel poles and towers shall be designed to prevent overturning.

The weight of concrete shall be assumed as 140 lb. per cu-ft. In good ground, the weight of "earth" (calculated at 30 deg. from the vertical) shall be assumed as 100 lb. per cu-ft. In swampy ground special measures shall be taken to prevent uplift or depression.

Concrete for foundations shall be well worked, very wet, and shall not be leaner than one part of Portland cement, three parts clean sharp sand, and six parts of broken stone, or one

part Portland cement to six parts of good gravel, free from loam or clay.

*65 The top of the concrete foundation or casing, shall be not less than 6 in. above the surface of the ground, nor less than 1 ft. above high water, except that no foundation need be higher than the base of the railroad company's rail, or the top of the traveled roadway.

66 When located in swampy ground, wooden crossing and next adjoining poles shall be set in barrels of broken stone or gravel, or in broken stone or timber footings.

67 When located in the sides of banks, or when subject to washouts, foundations shall be given additional depth, or be protected by cribbing or riprap.

*68 All foundations and pole settings shall be tamped in 6-in. layers, while back filling. It is desirable in back filling that the earth be suitably moistened.

WORKING UNIT STRESSES

Obtained by dividing the ultimate breaking strength by the factors of safety given in paragraph No. 34.

69 *Structural Steel:*

Tension (net section)	18,000	lb. per sq. in.
Shear	14,000	" " " "
Compression	$18{,}000-60\frac{L}{R}$	" " " "

70 *Rivets, Pins:*

Shear	10,000	lb. per sq. in.
Bearing	20,000	" " " "
Bending	20,000	" " " "

71 *Bolts:*

Shear	8,500	lb. per sq. in.
Bearing	17,000	" " " "
Bending	17,000	" " " "

72 *Wires and Cables:*

Copper, hard-drawn, solid, B. & S. gauge,	4/0, 3/0, 2/0—	25,000	lb. per sq. in.
" " " " "	1/0	27,500	" " " "
" " " " "	No. 1	28,500	" " " "
" " " " "	No. 2, 4, 6..	30,000	" " " "
" soft-drawn " " "	....	17,000	" " " "
" hard-drawn, stranded " "	....	30,000	" " " "
" soft-drawn, " " "	....	17,000	" " " "
Aluminum, hard-dr'n " " "	under 4/0 ..	12,000	" " " "
" " " " "	4/0 and over	11,500	" " " "

*73 *Untreated Timber:*

	Bending					Compression	
Eastern white cedar	600	lb.	per	sq.	in.	600	$(1 - \frac{L}{60D}$
Chestnut	850	"	"	"	"	850	"
Washington cedar	850	"	"	"	"	850	"
Idaho cedar	850	"	"	"	"	850	"
Port Orford cedar..............	1,150	"	"	"	"	1,150	"
Long-leaf yellow pine...........	1,000	"	"	"	"	1,000	"
Short-leaf yellow pine...........	800	"	"	"	"	800	"
Douglas fir	900	"	"	"	"	900	"
White oak	950	"	"	"	"	950	"
Red cedar	700	"	"	"	"	700	"
Bald cypress (heartwood).......	800	"	"	"	"	800	"
Redwood	650	"	"	"	"	650	"
Catalpa	500	"	"	"	"	500	"
Juniper	550	"	"	"	"	550	"

L = Length in inches.
D = Least side, or diameter, in inches.

APPENDICES

A—Wind and ice loads.

B—Tables and curves of conductor sags.

C—Specification for galvanizing for iron and steel.

D—Pole formulæ.

E—Drawings of typical crossings.

F—Calculations of typical crossings.

APPENDIX A

TABLE I

STEEL WIRE—STRANDED—GALVANIZED

Diam.	Number and Gauge of Wires	Area Square Inches	Ultimate Strength: Guy Wire	Ultimate Strength: Siemens Martin 75,000 lb	Ultimate Strength: High Tension 125,000 lb	Ultimate Strength: Ex. High Tension 187,000 lb	Load Per Lin. Ft. Vertical: Dead	Load Per Lin. Ft. Vertical: Dead + ½" Ice	Load Per Lin. Ft. Horizontal: 8.0 lb Per Sq. Ft. ½" Ice	Max. Load Per Lin. Ft. Plane of Resultant Class B Loading	E A E = 29,000,000
7/8"									1.250		
13/16"									1.208		
3/4"									1.167		
11/16"									1.125		
5/8"	7-5	0.2356		19,000	25,000	42,000			1.083		6,832,40c
9/16"	7-6½	0.1922		14,500	21,100	34,500	0.668	1.329	1.042		5,573,800
1/2"	7-8	0.1443	8,500	11,000	18,000	27,000	0.510	1.132	1.000	1 510	4,184,70c
7/16"	7-9	0.1204	6,500	9,000	15,000	22,500	0.415	0.998	0.958	1.383	3 491,60c
3/8"	7-11	0.0832	5,000	6,800	10,500	17,250	0.295	0.839	0.917	1.243	2,412,80
5/16"	7-12	0.0606	3,800	4,860	8,100	12,100	0.210	0.715	0.875	1 130	1 757,40

PROPERTIES OF WIRE MATERIAL

	Ultimate Strength Per Square In.	Elastic Limit	Mod. Elasticity E	Coef Expansion θ
Copper, solid, soft-drawn.........	32-34,000	28,000	12,000,000	0.0000096
" " hard-drawn	50-55-57-60,000	30-32-34-35,000	16,000 000	"
" stranded, soft-drawn......	34,000	28,000	12,000 000	"
" " hard-drawn	60,000	35,000	16,000 000	"
Aluminum, stranded	23-24,000	14,000	9,000,000	0.0000128
Steel, stranded, Siemens-Martin...	75,000		29,000,000	0.0000064
" " high-tension	125,000		"	"
" " ex-high-tension ..	187,000		"	"

NOTE—Class A Loading = dead load + 15.0 lbs. p. sq. ft. wind pressure.
Class B " = dead + ½" ice + 8.0 lbs. wind.
Class C " = dead + ¾" ice + 11.0 lbs. wind.

TABLE II

COPPER WIRE—STRANDED

Gauge B. & S.	Diam. Inches	Area Sq. In.	Hard Drawn: Ultimate Tension Lbs.	Hard Drawn: Allow. Tension	Soft Drawn: Ult. Tens'n Lbs.	Soft Drawn: Allow. Tens'n	Load per Lin. Foot Vertical: Dead	Vertical: Dead + ½ Ice	Vertical: Dead + ¾ Ice	Load per Lin. Foot Horizontal: 15.0 lb P.Sq. Ft.	Horizontal: 8.0 lb P.Sq.Ft. ½ Ice	Horizontal: 11.0 lb P.Sq.Ft. ¾ Ice	Max. Load per Lin. Foot Plan of Resultant: Class A Load'g	Class B Load'g	Class C Load'g	EA: E 16,000,000	EA: E 12,000,000
500,000	0.819	0.3924	23,540	11,750	13,340	6,650	1.525	2.345	2.989	1.024	1.213	2.126	1.837	2.640	3.668	6,278,400	4,708,800
450,000	0.770	0.3535	21,210	10,600	12,020	6,000	1.373	2.163	2.791	0.963	1.180	2.081	1.677	2.464	3.481	5,636,800	4,242,000
400,000	0.728	0.3141	18 860	9,400	10,680	5,350	1.220	1.984	2.599	0.910	1.152	2.042	1.522	2.294	3.305	5,025,600	3,769,200
350,000	0.679	0.2750	16,500	8,250	9,350	4,650	1.068	1.801	2.401	0.849	1.119	1.997	1.364	2.120	3.123	4,400,000	3,300,000
300,000	0.630	0.2360	14,160	7,100	8 025	4,000	0.915	1.618	2.203	0.788	1.087	1.953	1.208	1.949	2.944	3,776,000	2,832,000
250,000	0.590	0.1965	11,790	5,900	6 680	3,350	0.762	1.440	2.012	0.738	1.060	1.916	1.061	1.788	2.778	3,144,000	2,358,000
0000	0.530	0.1662	9 970	5,000	5,650	2,800	0.645	1.286	1.831	0.663	1.020	1.861	0.925	1.641	2.611	2,659,200	1,994 400
000	0.470	0.1318	7,910	3,950	4,480	2,250	0.513	1.116	1.651	0.588	0.980	1.806	0.780	1.485	2.446	2,108,800	1,581,600
00	0.420	0.1045	6,270	3,150	3,555	1,750	0.406	0.978	1.498	0.525	0.947	1.760	0.664	1.361	2.311	1,672,000	1,254,000
0	0.375	0.0829	4 970	2,500	2,820	1,400	0.322	0.866	1.372	0.469	0.917	1.719	0.569	1.261	2.199	1,326,400	994,800
1	0.330	0.0657	3,940	1,950	2,235	1,100	0.255	0.771	1.263	0.413	0.887	1.678	0.485	1.175	2.100	1 051,200	788,400
2	0.291	0.0521	3,130	1,550	1,770	900	0.203	0.695	1.174	0.364	0.861	1.642	0.417	1.107	2.019	833,600	625,200
3	0.261	0.0413	2,480	1,250	1,405	700	0.160	0.633	1.103	0.326	0.841	1.614	0.363	1.053	1.955	660,800	495,600
4	0.231	0.0328	1,970	1,000	1,115	550	0.127	0.582	1.042	0.289	0.821	1.587	0.316	1.006	1.899	524,800	393,600
5	0.206	0.0260	1,560	800	885	450	0.101	0.540	0.992	0.258	0.804	1.564	0.277	0.970	1.852	416,000	312,000
6	0.184	0.0206	1,235	600	700	350	0.080	0.505	0.951	0.230	0.789	1.543	0.243	0.936	1.813	329,600	247,200

TABLE III

COPPER WIRE—SOLID

0000	0.460	0.1662	8,310	4,150	5,650	2,800	0.641	1.238	1.770	0.575	0.973	1.797	0.861	1.575	2.522
000	0.410	0.1318	6 590	3,300	4,480	2,250	0.509	1.074	1.591	0.512	0.940	1.750	0.722	1.427	2.365
00	0.365	0.1045	5,220	2,600	3,555	1,750	0.403	0.940	1.443	0.456	0.910	1.709	0.608	1.309	2.237
0	0.325	0.0829	4,560	2,300	2,820	1,400	0.320	0.833	1.323	0.406	0.883	1.673	0.517	1.214	2.133
1	0.289	0.0657	3,740	1,850	2,235	1,100	0.253	0.744	1.223	0.362	0.860	1.640	0.442	1.137	2.046
2	0.258	0.0521	3,120	1,550	1,770	900	0.202	0.673	1.142	0.322	0.838	1.611	0.380	1.075	1.975

Gauge B. & S.	Ext. Diam. Inches	Area Sq. In.	Hard Drawn Ultimate Tension Lbs.	Hard Drawn Allow Tension	Soft Drawn Ult. Tens'n Lbs.	Soft Drawn Allow. Tens'n	Load per Lin. Foot Vertical Dead	Vertical Dead + ½" Ice	Vertical Dead + ¾" Ice	Load per Lin. Foot Horizontal 15.0 lb P.Sq. Ft.	Horizontal 8.0 lb P.Sq.Ft. ½" Ice	Horizontal 11.0 lb P.Sq.Ft. ¾" Ice	Max. Load per Lin. Foot Plan of Resultant Class A Load'g	Class B Load'g	Class C Load'g	E 16,000,000	EA E 12,000,000
0000	0.640	0.1662	8,310	4,150	5,650	2,800	0.767	1.476	2.064	0.800	1.093	1.961	1.108	1.837	2.847	2,659,200	1,994,400
000	0.593	0.1318	6,590	3,300	4,480	2,250	0.629	1.309	1.882	0.741	1.062	1.918	0.972	1.686	2.687	2,108.800	1,581,600
00	0.515	0.1045	5,220	2,600	3,555	1,750	0.502	1.133	1.682	0.644	1.010	1.847	0.818	1.518	2.498	1,672,000	1.254,000
0	0.500	0.0829	4,560	2,300	2,820	1,400	0.407	1.029	1.573	0.625	1.000	1.833	0.746	1.434	2,415	1,326,400	994,800
1	0.453	0.0657	3,740	1,850	2,235	1,100	0.316	0.909	1.438	0.564	0.968	1.790	0.646	1.328	2,296	1,051,200	788,400
2	0.437	0.0521	3,120	1,550	1,770	900	0.260	0.843	1.367	0.546	0.958	1.775	0.605	1.276	2.240	833,600	625,200
3	0.406	0.0413	2,480	1,250	1.405	700	0.199	0.763	1.278	0.507	0.937	1.747	0.545	1.208	2.164	660,800	495,600
4	0.359	0.0328	1,960	1,000	1,115	550	0.164	0.698	1.199	0.449	0.906	1.704	0.478	1.143	2.083	524,800	393,600
5	0.344	0.0260	1,560	800	885	450	0.135	0.660	1.146	0.430	0.896	1.690	0.451	1.113	2.042	416,000	312,000
6	0.328	0.0206	1,240	600	700	350	0.112	0.627	1.118	0.410	0.885	1.675	0.425	1.084	2.014	329,600	247,200

TABLE V

ALUMINUM WIRE—STRANDED

Gauge B. & S.	Ext. Diam. Inches	Area Sq. In.	Ultimate Tension Lbs.	Allow Tension	Dead	Dead + ½" Ice	Dead + ¾" Ice	15.0 lb P.Sq. Ft.	8.0 lb P.Sq.Ft. ½" Ice	11.0 lb P.Sq.Ft. ¾" Ice	Class A Load'g	Class B Load'g	Class C Load'g	E 9 000.000
500,000	0.814	0.3924	9,025	4,500	0.460	1.280	1.919	1.018	1.209	2.121	1.117	1.762	2.860	3,531,600
450,000	0.772	0.3535	8,130	4,050	0.414	1.205	1.834	0.965	1.181	2.082	1.050	1.687	2.775	3,181,500
400.000	0.725	0.3141	7,225	3,600	0.368	1.130	1.744	0.906	1,150	2.040	0.977	1.612	2.684	2.826,900
350,000	0.679	0.2750	6,325	3,150	0.322	1.055	1.655	0.849	1.119	1.997	0.908	1.538	2.594	2,475,000
300,000	0.621	0.2360	5,430	2,700	0.276	0.973	1.555	0.776	1.081	1.944	0.823	1.454	2.489	2,124,000
250,000	0.567	0.1965	4,520	2,250	0.230	0.894	1.459	0.709	1.045	1.895	0.745	1.375	2.392	1,768,500
0000	0.522	0.1662	3,820	1,900	0.195	0.831	1.382	0.652	1.015	1.853	0.681	1,312	2,312	1,495,800
000	0.464	0.1318	3,160	1,600	0.155	0.755	1.288	0.580	0.976	1.800	0.600	1.234	2.213	1,186,200
00	0.414	0.1045	2,510	1,250	0.122	0.691	1.208	0.518	0.943	1.754	0.532	1.168	2.130	940,500
0	0,368	0,0879	1,990	1,000	0.097	0,637	1.140	0.460	0.912	1.712	0.470	1.112	2.057	746,100
1	0.328	0.0657	1,575	800	0.077	0.592	1.082	0.410	0.885	1.676	0.417	1.065	1.995	591,300
2	0.291	0.0521	1,250	600	0.061	0.533	1.032	0.364	0.861	1.642	0.368	1.023	1.939	468,900
3	0.261	0.0413	990	500	0.049	0.522	0.992	0.326	0.841	1.614	0.329	0.990	1.894	371,700
4	0.231	0.0328	790	400	0.039	0.494	0.954	0.289	0.821	1.587	0.292	0.958	1.846	295,200

APPENDIX B

Sags

In the following tables and curves are given sags at which conductors shall be strung in order that, when loaded with the specified requirement of one-half inch of ice and a wind load of 8.0 pounds per square foot of projected area at 0 degrees fahrenheit, the tension in the conductor will not exceed the allowable value of one-half the ultimate strength of the conductor as given in section above. The sags given in the tables for 1x degrees fahrenheit are greater in every case than the vertical opponent of the sags at 0 degrees fahrenheit under the maximum wind and ice load.

The moduli of elasticity and coefficients of expansion used are given in Appendix A, viz.:

Modulus of Elasticity

Copper, hard-drawn, solid or stranded........	16,000,000
Copper, soft-drawn, solid	12,000,000
Aluminum, hard-drawn	9,000,000

Temperature Coefficient.

Copper	.0000090
Aluminum	.0000128

MINIMUM SAGS FOR STRANDED HARD-DRAWN BARE COPPER WIRES

Span in Feet

No. 4/0 B. & S.	Temp. F.	100 or less Inches	125 Inches	150 Inches	200 Inches	250 Sags Inches	300 Inches	400 Feet	500 Feet	600 Feet
	—20	2	3	5	8	13	20	3.5	6	10
	0	2	4	5	9	14	22	3.5	6 5	10.5
	20	3	4	6	10	16	24	4 .	7	11.5
	40	3	4	6	11	18	27	4.5	8	12
	60	3	5	7	13	20	31	5	8.5	13
	80	4	6	8	15	24	35	5.5	9	13.5
	100	4	7	10	17	27	40	6	10	14.5
	120	5	8	12	20	31	46	7	10.5	15

Span in Feet

o. 3/0 . & S. Temp F.	100 or less Inches	125 Inches	150 Inches	200 Inches	250 Sags Inches	300 Inches	400 Feet	500 Feet	600 Feet
—20	2	3	5	8	13	21	4	7	12
0	2	4	5	9	15	23	4	7.5	12.5
20	3	4	6	10	17	25	4.5	8.5	13.5
40	3	4	6	12	19	29	5	9	14
60	3	5	7	13	22	33	6	9.5	15
80	4	6	8	15	25	38	6.5	10.5	15.5
100	4	7	10	18	29	43	7	11	16
120	5	8	12	21	34	49	7.5	12	17

Span in Feet

o. 2/0 . & S. Temp. F.	100 or less Inches	125 Inches	150 Inches	200 Inches	250 Sags Inches	300 Inches	400 Feet	500 Feet	600 Feet
—20	2	3	5	9	14	23	4.5	9	15
0	2	4	5	10	16	26	5	9.5	15.5
20	3	4	6	11	18	29	5.5	10	16
40	3	4	7	12	21	33	6	11	17
60	3	5	7	14	24	37	6.5	11.5	17.5
80	4	6	9	16	28	43	7	12	18
100	5	7	10	19	32	48	8	12.5	18.5
120	6	9	12	23	37	54	8.5	13.5	19.5

Span in Feet

No. 0 . & S. Temp. F.	100 or less Inches	125 Inches	150 Inches	200 Sags Inches	250 Inches	300 Feet	400 Feet	500 Feet	600 Feet
—20	2	3	5	9	16	2.5	5.5	11.5	18.5
0	2	4	5	10	18	2.5	6.5	12	19
20	3	4	6	11	21	3	7	12.5	19.5
40	3	5	7	13	24	3.5	7.5	13	20
60	3	5	8	15	27	4	8	14	20.5
80	4	6	9	18	32	4.5	8.5	14.5	21.5
100	5	7	11	21	37	5	9	15	22
120	6	9	13	25	42	5	9.5	15.5	22 5

MINIMUM SAGS FOR SOLID HARD-DRAWN BARE COPPER WIRE

Span in Feet

No. 6 . & S. Temp. F.	100 or less Inches	125 Inches	150 Inches	200 Feet	250 Sags Feet	300 Feet	400 Feet
—20	3	8	22	5.5	10	15	30
0	4	10	26	6.0	10	15	30
20	5	13	30	6	10 5	15.5	30.5
40	6	16	33	6	10.5	15.5	30.5
60	8	19	36	6.5	11	16	31
80	10	22	39	6.5	11	16	31
100	13	25	41	7	11.5	16.5	31
120	16	28	44	7	11.5	16.5	31.5

Span in Feet

No. 1 B. & S.

Temp. F.	100 or less Inches	125 Inches	150 Inches	200 Inches	250 Inches	300 Feet	400 Feet	500 Feet	600 Feet
				Sags					
—20	2	4	5	10	19	3	8	14.5	23
0	3	4	6	11	22	3.5	8 5	15	23.5
20	3	4	6	13	25	4	9	16	24
40	3	5	7	15	30	4.5	9 5	16	24.5
60	4	6	8	18	34	5	10	17	25
80	4	7	10	21	39	5.5	10 5	17	25.5
100	5	8	12	25	44	6	11	18	26
120	6	10	16	30	49	6	11 5	18	26.5

Span in Feet

No. 2 B. & S.

Temp. F.	100 or less Inches	125 Inches	150 Inches	200 Inches	250 Inches	300 Feet	400 Feet	500 Feet	600 Feet
				Sags					
—20	2	4	5	12	25	4	10 5	18.5	29
0	3	4	6	14	29	4.5	11	19	29.5
20	3	5	7	16	33	5	11.5	19.5	30
40	3	5	8	19	39	5.5	12	20	30.5
60	4	6	10	23	43	6.0	12.5	20.5	31
80	4	7	12	27	48	6 5	13	21	31
100	5	9	14	31	53	7	13	21.5	31.5
120	7	11	18	35	58	7.5	13.5	22	32

Span in Feet

No. 3 B. & S.

Temp. F.	100 or less Inches	125 Inches	150 Inches	200 Inches	250 Feet	300 Feet	400 Feet	500 Feet	600 Feet
				Sags					
—20	3	4	6	17	3	6	14	24	37.5
0	3	4	7	20	3.5	6.5	14.5	24.5	37.5
20	3	5	8	23	4	7	15	25	38
40	3	6	10	27	4.5	7.5	15	25	38
60	4	7	12	30	5	8	15.5	25.5	38.5
80	5	9	14	35	5.5	8.5	16	26	39
100	6	11	17	39	5.5	8.5	16.5	26	39
120	8	14	22	44	6	9	16.5	26.5	39.5

Span in Feet

No. 4 B. & S.

Temp. F.	100 or less Inches	125 Inches	150 Inches	200 Inches	250 Feet	300 Feet	400 Feet	500 Feet	600 Feet
				Sags					
—20	3	4	8	25	5	9	18	31	46
0	3	5	9	29	5.5	9	18.5	31.5	46
20	3	6	11	33	6	9.5	19	31.5	46.5
40	4	7	13	38	6.5	10	19	32	46.5
60	4	9	16	42	6.5	10	19.5	32.5	47
80	5	11	19	46	7	10.5	19.5	32.5	47.5
100	7	13	23	50	7.5	11	20	32.5	47.5
120	9	16	27	54	7.5	11	20.5	33	48

MINIMUM SAGS FOR STRANDED BARE ALUMINUM WIRES

SPAN IN FEET

No. 4/0 B. & S.	Temp F.	80 or less In.	100 In.	125 In.	150 In.	200 Sags In.	250 Feet	300 Feet	400 Feet	500 Feet	600 Feet
	—20°	1	2	3	5	11	2.5	5	11	19	29
	0	1	2	3	6	15	3	5.5	12	19.5	29.5
	20	2	3	5	8	21	3.5	6	12.5	20.5	30
	40	2	4	7	11	27	4.5	7	13	21	31
	60	4	6	11	17	34	5	7.5	13.5	21.5	31.5
	80	6	10	16	22	41	5.5	8	14	22	32
	100	10	14	20	27	46	6	8.5	14.5	22.5	33
	120	13	18	25	32	52	6 5	9	15	23	33.5

SPAN IN FEET

No. 3/0 B. & S.	Temp. F	80 or less In.	100 In.	125 In.	150 In.	200 Sags In.	250 Feet	300 Feet	400 Feet	500 Feet	600 Feet
	—20	1	2	3	5	12	3	5.5	13	22	33.5
	0	1	2	4	6	17	3.5	6.5	13.5	22.5	34
	20	2	3	5	8	24	4.5	7	14	23	34.5
	40	2	4	7	12	31	5	7.5	14.5	23.5	35
	60	3	5	11	18	38	5.5	8	15	24	35.5
	80	6	9	16	23	43	6	8.5	15.5	24.5	36
	100	10	13	20	29	49	6.5	9	16	25	36.5
	120	13	17	25	33	54	7	9.5	16.5	25.5	37

SPAN IN FEET

No. 2/0 B. & S.	Temp. F.	80 or less In.	100 In.	125 In.	150 In.	200 Sags Feet	250 Feet	300 Feet	400 Feet	500 Feet	600 Feet
	—20	1	2	3	6	2	5	8.5	16.5	28	42
	0	2	2	4	8	2.5	5.5	9	17	28.5	42.5
	20	2	3	6	12	3	6	9	17.5	29	43
	40	2	4	9	18	3.5	6.5	9.5	18	29.5	43
	60	4	7	14	24	4	7	10	18.5	29.5	43.5
	80	7	12	19	29	4.5	7	10.5	19	30	44
	100	10	16	24	33	5	7.5	11	19.5	30.5	44.5
	120	14	19	28	38	5.5	8	11.5	20	31	44.5

SPAN IN FEET

No. 0 B. & S.	Temp. F.	80 or less In.	100 In.	125 In.	150 In.	200 Sags Feet	250 Feet	300 Feet	400 Feet	500 Feet
	—20	1	2	4	9	3.5	7	10.5	21	36.5
	0	2	3	6	14	4	7	11	21.5	36.5
	20	2	4	8	20	4.5	7.5	11.5	22	37
	40	3	6	13	26	5	8	12	22	37
	60	5	10	18	31	5	8.5	12	22.5	37.5
	80	8	14	23	35	5.5	8.5	12.5	23	38
	100	12	18	27	39	6	9	13	23	38
	120	15	21	31	43	6	9.5	13.5	23.5	38.5

Span in Feet

No. 1 B. & S.	Temp. F.	80 or less	100	125	150	200	250	300	400	500
					Sags					
		In.	In.	In.	In.	Feet	Feet	Feet	Feet	Feet
	—20	1	3	7	20	5	9	13.5	26.5	43.5
	0	2	4	11	25	5.5	9	14	27	43.5
	20	2	5	16	30	5 5	9.5	14.5	27	44
	40	4	9	21	34	6	10	14.5	27.5	44
	60	7	13	25	39	6.5	10	15	27.5	44.5
	80	10	18	29	42	6 5	10.5	15.5	28	44.5
	100	14	21	32	45	7	11	15.5	28	45
	120	17	24	36	49	7	11	16	28.5	45

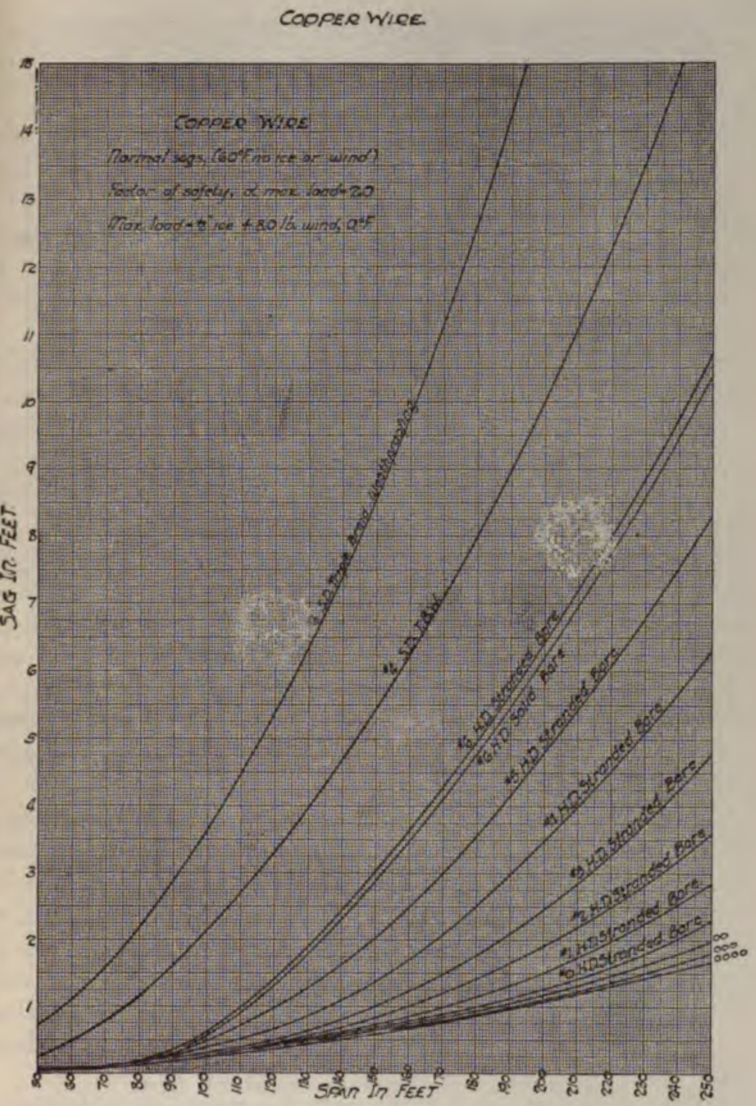
MINIMUM SAGS FOR COVERED SOLID SOFT COPPER WIRE

Span in Feet

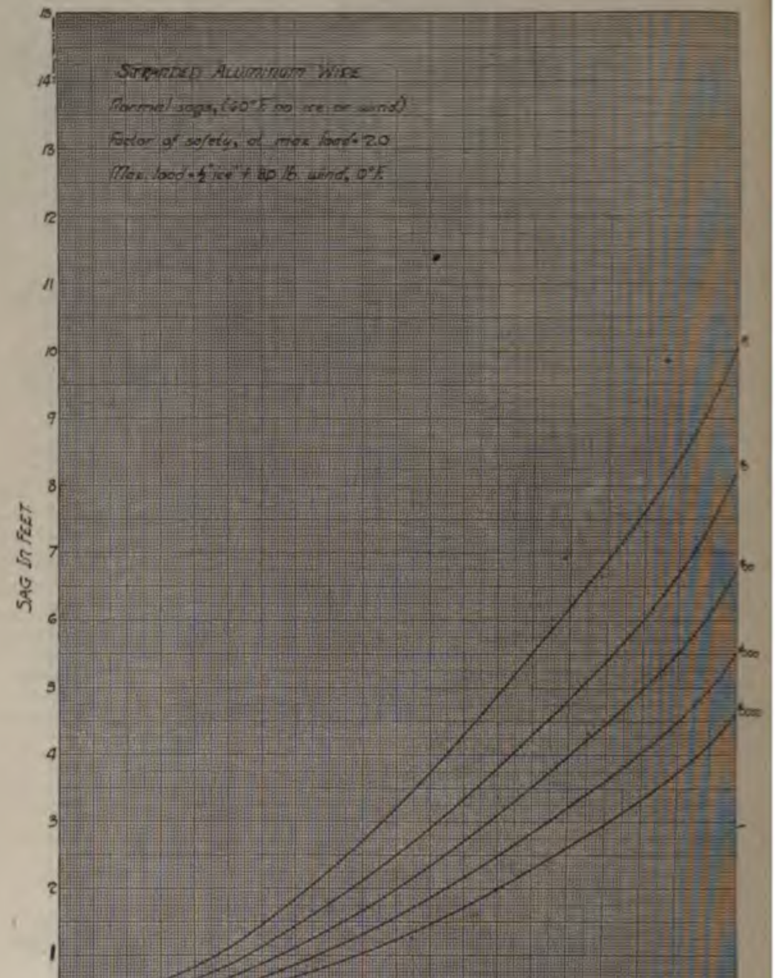
No. 4 B. & S.	Temp. F.	60	80	100	125	150	200	250	300
					Sags				
		Inches	Inches	Inches	Inches	Feet	Feet	Feet	Feet
	—20	3	7	17	35	5	9.5	16	23.5
	0	3	8	19	37	5	10	16	24
	20	4	10	21	39	5	10	16	24
	40	5	12	23	41	5.5	10	16.5	24
	60	6	14	25	43	5.5	10	16.5	24.5
	80	8	16	27	45	5.5	10.5	16.5	24.5
	100	10	17	29	46	6	10.5	16.5	24.5
	120	11	19	30	48	6	10.5	17	24.5

Span in Feet

No. 6 B. & S.	Temp. F.	60	80	100	125	150	200	250
					Sags			
		Inches	Inches	Inches	Feet	Feet	Feet	Feet
	—20	7	21	38	5.5	8.5	16	26
	0	9	22	40	6	8.5	16	26.5
	20	10	24	41	6	8.5	16	26.5
	40	12	25	42	6	9	16	26.5
	60	13	26	43	6	9	16	26.5
	80	14	27	45	6	9.	16.5	26.5
	100	15	29	46	6.5	9	16.5	26.5
	120	17	30	47	6.5	9	16.5	27



SAG CURVES FOR COPPER WIRE



Sag Curves for Stranded Aluminum Wire

APPENDIX C

SPECIFICATION FOR GALVANIZING FOR IRON OR STEEL

These specifications give in detail the test to be applied to galvanized material. All specimens shall be capable of withstanding these tests.

A. Coating. The galvanizing shall consist of a continuous coating of pure zinc of uniform thickness, and so applied that it adheres firmly to the surface of the iron or steel. The finished product shall be smooth.

B. Cleaning. The samples shall be cleaned before testing, first with carbona, benzine or turpentine, and cotton waste (not with a brush), and then thoroughly rinsed in clean water and wiped dry with clean cotton waste.

The sample shall be clean and dry before each immersion in the solution.

C. Solution. The standard solution of copper sulphate shall consist of commercial copper sulphate crystals dissolved in cold water, about in the proportion of 36 parts, by weight, of crystals to 100 parts, by weight, of water. The solution shall be neutralized by the addition of an excess of chemically pure cupric oxide (Cu O). The presence of an excess of cupric oxide will be shown by the sediment of this reagent of the bottom of the containing vessel.

The neutralized solution shall be filtered before using by passing through filter paper. The filtered solution shall have a specific gravity of 1.186 at 65 deg. fahr. (reading the scale at the level of the solution) at the beginning of each test. In case the filtered solution is high in specific gravity, clean water shall be added to reduce the specific gravity at 1.186 at 65 deg. fahr. In case the filtered solution is low in specific gravity, filtered solution of a higher specific gravity shall be added to make the specific gravity 1.186 at 65 deg. fahr.

As soon as the stronger solution is taken from the vessel containing the unfiltered neutralized stock solution, additional crystals and water must be added to the stock solution. An excess of cupric oxide shall always be kept in the unfiltered stock solution.

D. Quantity of Solution. Wire samples shall be tested in a glass jar of at least two (2) inches inside diameter. The jar without the wire samples shall be filled with standard solution to a depth of at least four (4) inches. Hardware samples shall be tested in a glass or earthenware jar containing at least one-half (½) pint of standard solution for each hardware sample.

Solution shall not be used for more than one series of four immersions.

E. Samples. Not more than seven wires shall be simultaneously immersed, and not more than one sample of galvanized material other than wire shall be immersed in the specified quantity of solution.

The samples shall not be grouped or twisted together, but shall be well separated so as to permit the action of the solution to be uniform upon all immersed portions of the samples.

F. Test. Clean and dry samples shall be immersed in the required quantity of standard solution in accordance with the following cycle of immersions.

The temperature of the solution shall be maintained between 62 deg. and 68 deg. fahr. at all times during the following test.

First. Immerse for one minute, wash and wipe dry.

Second. Immerse for one minute, wash and wipe dry.

Third. Immerse for one minute, wash and wipe dry.

Fourth. Immerse for one minute, wash and wipe dry.

After each immersion the samples shall be immediately washed in clean water having a temperature between 62 deg. and 68 deg. fahr., and wiped dry with cotton waste.

In the case of No. 14 galvanized iron or steel wire, the time of the fourth immersion shall be reduced to one-half minute.

G. Rejection. If after the test described in Section F there should be a bright metallic copper deposit upon the samples, the lot represented by the sample shall be rejected.

Copper deposits on zinc or within one inch of the cut end shall not be considered causes for rejection.

In the case of a failure of only one wire in a group of seven wires immersed together, or if there is a reasonable doubt as to the copper deposit, two check tests shall be made on these seven wires and the lot reported in accordance with the majority of the sets of tests.

Note

The equipment necessary for the tests herein outlined is as follows:

Filter paper.

Commercial copper sulphate crystals.

Chemically pure cupric oxide (Cu O).

Running water.

Warm water or ice as per needs.

Carbona, benzine or turpentine.

Glass jars at least two inches inside diameter by at least four and one-half inches high.

Glass or earthenware jars for hardware samples.

Vessel for washing samples.

Tray for holding jars of stock solution.

Jars, bottles and porcelain basket for stock solution.

Cotton waste.

Hydrometer cylinder 3 in. diameter by 15 in. high.

Thermometer with large fahrenheit scale correct at 62 and 68 deg.

Hydrometer correct at 1.186 at 65 deg. fahr.

APPENDIX D

POLE FORMULÆ

A pole is essentially a beam fixed at one end. The ordinary beam formulæ apply.

The strength of a pole is given by the formula

$$M = \frac{f\ I}{y}$$

when M = moment of the forces about the ground line (or other point of which the strength is being considered)

f = maximum fiber stress.

I = moment of inertia of section of pole.

y = distance from center to most strained fiber.

For a pole of circular cross section

$$M = \frac{f\ \pi\ D^3}{384} \text{ ft. lbs.}$$

where D = the diameter of the pole in inches and the moment arms of the forces are expressed in feet.

f is the maximum ultimate fiber stress or the allowable working fiber stress in pounds per square inch according as the ultimate strength or safe working strength of the pole is desired

FORCES ACTING ON A POLE TRANSVERSELY:

Wind pressure on pole.

" " " conductors.

The approximate moment at the ground due to wind pressure on the pole would be

$$M_p = \frac{P\ H^2\ (D + 2D_2) \text{ ft. lbs.}}{72}$$

P = wind pressure in pounds per square foot of projected area of pole.

H = height of pole in feet.

D_1 = diameter of pole at ground in inches.

D_2 = " " " " top in inches.

The moment at the ground due to wind pressure on the wires would be

$$Mc = \frac{P_2\ L\ n\ d\ (S_1 + S_2) \text{ ft. lb}}{24}$$

P_2 = wind pressure in pounds per square foot of projected area of wires.

L = Height of wires above ground in feet.

n = number of wires.

d = diameter of conductor loaded with ice, in inches.

S_1 and S_2 = lengths of adjacent spans in feet.

The total moment is the sum of M_p, Mc_1, Mc_2, etc.

Example: POLES.

Length of pole 40′.

Height of pole above ground 34′.

Length of adjacent spans 100′ and 120′.

Timber—Eastern white cedar.

WIRES:

One No. 0 wire on top of pole.

Two No. 0 wires on crossarm 3′ below top.

To find dimensions of cedar pole to give factor of safety of 6 with a wind pressure of 8 pounds per square foot projected area on wires covered with one-half inch of ice and 13 pounds per square foot projected area on poles.

Wind pressure on upper wire

Diameter of No. 0 wire = .37″.

" " " " " covered with ½″ ice = 1.37″

$$Mc_1 = \frac{P_2 \ L \ n \ d \ (S_1 + S_2) \text{ ft. lbs.}}{24}$$

$$Mc_1 = \frac{8 \times 34 \times 1 \times 1.37 \ (100 + 120)}{24} = 3{,}420 \text{ ft. lbs.}$$

Wind pressure on 2 lower wires

$$Mc_2 = \frac{8 \times 31 \times 2 \times 1.37 \ (100 + 120)}{24} = 6{,}230 \text{ ft. lbs.}$$

Wind pressure on pole

assuming diameters at butt and top to be 17″ and 8″

$$Mp = \frac{P \ H^2 \ (D_1 + 2D_2) \text{ ft. lbs.}}{72}$$

$$Mp = \frac{13 \times 34^2 \times 33}{72} = 6{,}875 \text{ ft. lbs.}$$

(If the result gives dimensions of poles much different from the values assumed, a second approximation should be made.)

Total moment = 16,525 ft. lbs.

$$M = \frac{f \pi D_1^3}{384} \text{ ft. lbs.}$$

For eastern white cedar f = 600 lbs. per sq. in.

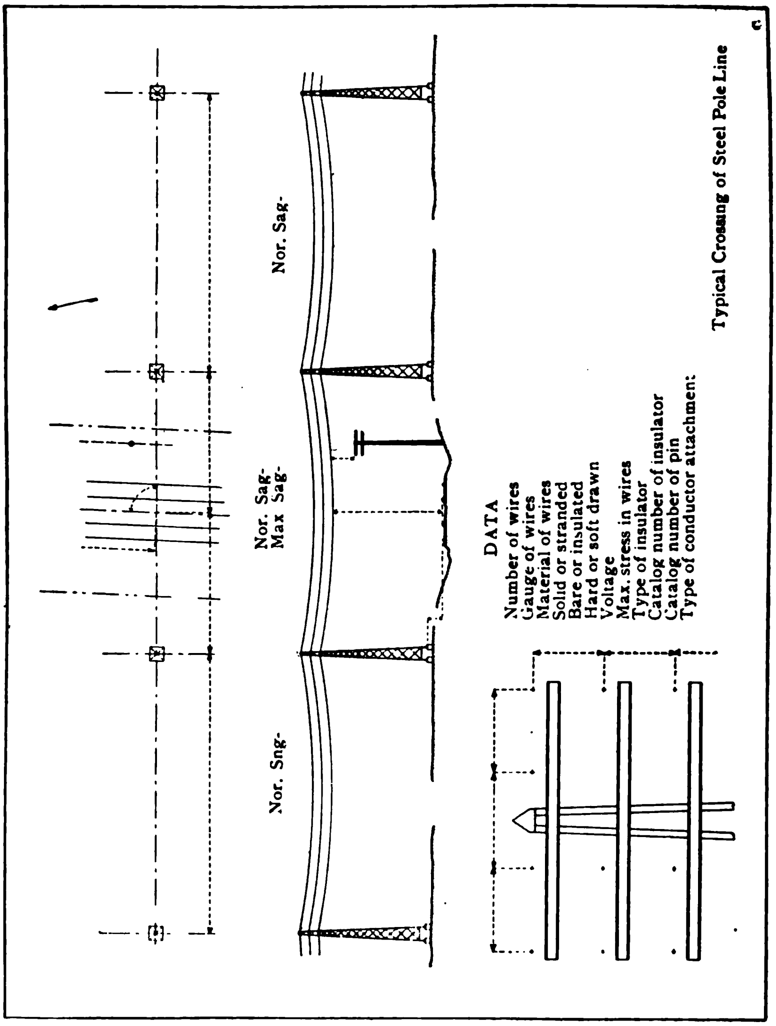
$$\frac{600 \pi D_1^3}{384} = 16.525$$

$$4.91 D_1^3 = 16,525$$

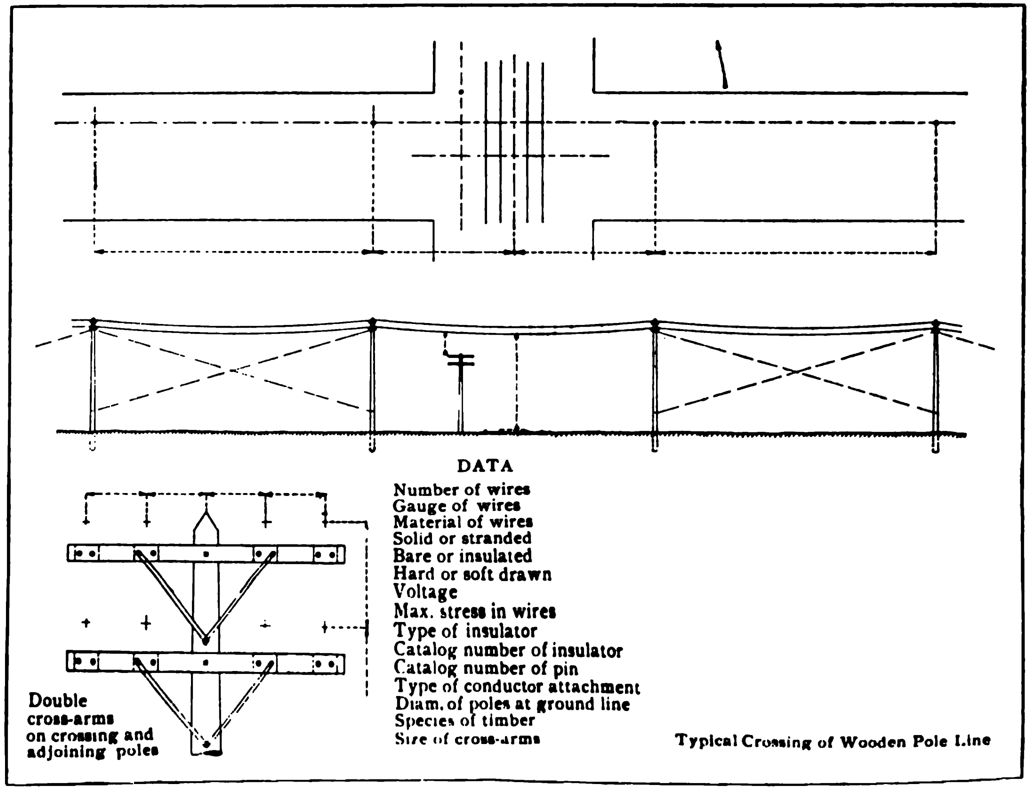
$$D_1^3 = 3,370 \quad D = 15''$$

Circumference at ground line = 47.2".

APPENDIX E



Typical Crossing of Steel Pole Line



Typical Crossing of Wooden Pole Line

COMMITTEE ON OVERHEAD LINE CONSTRUCTION
NATIONAL ELECTRIC LIGHT ASSOCIATION

FARLEY OSGOOD, Chairman, General Superintendent, Public Service Electric Co., Newark, N. J.

F. B. H. PAINE, General Manager, Niagara, Lockport & Ontario Power Co., Buffalo, N. Y.

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F. L. RHODES, Outside Plant Engineer, American Telephone & Telegraph Co., New York City.

PERCY THOMAS, Consulting Engineer, New York City.

H. M. HOPE, Engineer, Stone and Webster Engineering Corporation, Boston, Mass.

R. D. COOMBS, Consulting Engineer, Fitzpatrick and Coombs, Inc., New York City.

THOS. SPROULE, Assistant Engineer, Philadelphia Electric Co., Philadelphia, Pa.

W. T. OVIATT, General Superintendent, Narragansett Lighting Co., Providence, R. I.

J. F. DOSTAL, Superintendent, Denver Gas & Electric Co., Denver, Colo.

A. S. RICHEY, Consulting Engineer, Worcester, Mass.

GEO. A. CELLAR, Superintendent Telegraph, P. R. R. Lines West, Pittsburg, Pa.

GEO. H. LUKES, North Shore Electric Co., Chicago, Ill.

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*A. O. CUNNINGHAM, Chief Engineer, Wabash Railroad, St. Louis, Mo.

W. W. DRINKER, Assistant Engineer, Erie Railroad Co., New York City.

GEO. GIBBS, Chief Engineer, Electric Traction & Station Construction, Pennsylvania Tunnel & Terminal Railroad Co., New York City.

*G. A. HARWOOD, Chief Engineer, Electric Zone Improvements, New York Central & Hudson River Railroad Co., New York City.

E. B. KATTE, Chief Engineer Electric Traction, New York Central & Hudson River Railroad Co., New York City.

W. S. KINNEAR, President Kansas City Terminal Railway, Kansas City, Mo.

C. E. LINDSAY, Division Engineer, New York Central & Hudson River Railroad Co., Albany, N. Y.

E. H. MCHENRY, Vice-President, New York, New Haven & Hartford Railroad Co., New Haven, Conn.

*W. S. MURRAY, Electrical Engineer, New York, New Haven & Hartford Railroad Co., New Haven, Conn.

J. A. PEABODY, Signal Engineer, Chicago & Northwestern Railway, Chicago, Ill.

*Sub-committee.

POSTAL TELEGRAPH-CABLE COMPANY
EXECUTIVE OFFICES
253 BROADWAY

Charles C. Adams
Second Vice-President

New York, January 31, 1911.

Proposed specification for overhead crossings.

Mr. Farley Osgood, Chairman,
Overhead Line Construction Committee,
763 Broad Street, Newark, N. J.

Dear Sir:—Referring to your letter of January 26th, with a draft of the proposed overhead crossing specifications.

Our Engineers have reviewed this draft and it has their approval.

Yours truly,
C. C. Adams,
Vice-President.

THE WESTERN UNION TELEGRAPH COMPANY
195 BROADWAY

R. E. Chetwood
Engineer of Construction

New York, April 28, 1911.

Subject: Specifications for Overhead Crossings of Electric Light and Power Lines.

Mr. Farley Osgood, Chairman,
National Electric Light Association,
Overhead Line Construction Committee,
763 Broad Street, Newark, N. J.

Dear Sir:—Regarding the specifications for overhead crossings of electric light and power lines, which your Committee is to recommend to the National Electric Light Association for approval at its Convention in May and which I understand have already been approved by Committees representing the American Institute of Electrical Engineers: American Electric Railway Association; American Railway Engineering and Maintenance of Way Association, and the Association of Railway Telegraph Superintendents, this is to say that the specifications are satisfactory and meet with the approval of the Western Union Telegraph Company.

Yours truly,
R. E. Chetwood,
Engineer of Construction.

AMERICAN TELEPHONE AND TELEGRAPH COMPANY

15 DEY STREET

JOHN J. CARTY
Chief Engineer

NEW YORK, April 24, 1911.
April 18—33230—462.

Subject: Overhead Line Construction Specifications.

MR. FARLEY OSGOOD, Chairman,
Overhead Line Construction Committee,
National Electric Light Association,
763 Broad Street, Newark, N. J.

DEAR SIR:—Replying to your letter of the 18th of this month regarding the specifications drawn by the Overhead Line Construction Committee of the National Electric Light Association, I have to say that it is my understanding that the specifications which you refer to in your letter provide for the form of construction to be used for overhead crossings of electric light and power lines and that they are those recommended in the joint report of the Committee on Overhead Line Construction of the National Electric Light Association, the High-Tension Transmission Committee of the American Institute of Electrical Engineers, the Committee on Power Distribution of the American Electric Railway Association, the Committee on High-Tension Wire Crossings of the Association of Railway Telegraph Superintendents, and the Sub-Committee of Committee on Electricity of the American Railway Engineering and Maintenance of Way Association. You are hereby authorized to say that the above-mentioned specifications have the approval of this department.

Yours truly,
J. J. CARTY,
Chief Engineer.

THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD COMPANY

OFFICE OF
VICE-PRESIDENT

NEW HAVEN, CONN., April 24, 1911.

MR. FARLEY OSGOOD,
763 Broad Street, Newark, N. J.

DEAR SIR:—A meeting of the full committee appointed by the American Railway Association, to consider the subject of overhead electrical crossings, was held in New York on April 14th, at which the Sub-Committee presented its report with the recommendation for its adoption, and I beg to advise that while the Committee has not finally acted upon it, that it has been favorably received.

Yours truly,
E. H. MCHENRY,
Vice-President.

DISCUSSION

Mr. D. F. McGee, Portland, Ore.: I believe that the Committee which has prepared this Report deserves much credit for the work it has done. I must, however, enter an objection to any action being taken by the Committee at this time towards approving or endorsing the specifications given. I represent a company which operates on the Pacific Coast. We have hundreds of miles of high-voltage transmission lines. Our distributing lines serve a territory which is very sparsely settled. Our distributing voltages are 6600 and 11,000 volts. We are only one of a large number of companies operating under similar conditions. The adoption, as a standard, of 5000 volts as a maximum which we could use would put us out of business. Our sub-stations are approximately 20 miles apart. We serve towns of 500, 1000, 2000, 3000 people, and our distributing voltages in those towns is invariably 6600.

I am a member of the Committee of the Northwest Association, and have had conference with the State authorities in Washington, who, last year, adopted rules for overhead line construction in the form of a statute. We have a Public Service Commission in the State of Oregon, and I am a member of a committee which is now having conference meetings with the engineer of the Commission in order to formulate rules for overhead line construction in that State. We have tentatively adopted—I think the matter will be decided within the next few days—a rule setting the limit of voltage at 15,000, similar to what has been done in the State of California, and, I think, it is a matter of much importance to each and every one of us that we should not go on record here as stating that we are willing to make a standard form of construction of not over 5000 volts. We have had no accidents whatever, and I feel we would be making a mistake to adopt these specifications.

Mr. D. W. Roper, Chicago: On page 581 appear some specifications for galvanizing. A number of companies are now using sherardized material, and if these specifications are suitable for sherardizing material, I would suggest that the wording be changed. If they are not suitable, I would like to recommend that the Committee prepare specifications for sherardizing material also.

MR. T. K. STEVENSON, New York City: In these specifications, under Material, there is a statement that copper-covered steel wire may be used. I mention this because the Committee has also approved specifications for copper-clad steel wire. On the other hand, as it proceeds with these specifications it states: "The conductors should be of copper, aluminum, or other noncorrodible material," and so forth, and on other pages gives the unit working stresses for copper, aluminum and iron. I wonder if it would not be possible to make somewhat clearer mention of the use of copper and more definite specifications as to its use.

MR. L. G. COLEMAN, Bartlesville, Okla.: I just wish to state for the benefit of the speakers that sherardizing is referred to in paragraph 63.

MR. GEORGE A. SAWIN, Newark, N. J.: In the preface to this report, a definite recommendation is made with respect to the creation of a joint committee as follows:

"The Committee feels that on account of the great amount of attention given to this specification work by other Associations at interest, it is desirable to broaden the scope of the Overhead Line Construction Committee, and to change the title to the 'National Joint Committee on Overhead Line Construction,' thus eliminating any one Society as the sponsor for the Committee, and making the organization of the Committee sufficiently strong and of such general personnel as to cover all the requirements for overhead line construction work, and to cover them on a completely mutual basis.

"It is felt that if this can be accomplished, various branches of line work can be handled by sub-committees of this general National Joint Committee, and that no conflicting specifications would be likely to result from such a community of interest in the National Joint Committee.

"There has not been time to prepare for this Convention a distinct plan of creation for this National Joint Committee, but your Committee asks the authority of the Association to formulate a National Joint Committee as suggested, in any way which may seem best, which method shall carry the approval of the Executive Committee of the National Electric Light Association before final action on the part of your representatives is taken.

"We cannot urge too strongly the necessity of such action and the great amount of good that can come from a National Joint Committee as described, and tentative discussions with the representatives of our sister Associations lead us to state here that this plan will unquestionably receive general approval, as not only feasible but most desirable of accomplishment."

That seems to be a very good suggestion, and, in order to get it formally before the Session, I move you that the recommendation for a Joint Committee be approved by the Technical Section, and that the matter be referred to the Executive Committee for the necessary action to make the suggestion of the Committee possible.

(The motion was duly seconded and carried.)

MR. ERNEST H. DAVIS, Williamsport, Pa.: This does not commit the Section to the request that either the Class A members or the Executive Committee adopt the specification in its present form? Do I understand that this refers only to the formation of the new joint committee?

THE CHAIRMAN: That is all.

MR. R. J. McCLELLAN, New York City: I want to protest against the adoption of these specifications as they stand. The transmission companies which operate in different States would be put to great hardship in following these specifications. Really, we, who are operating long interstate lines, are constantly faced with the specifications prepared by the National body, people saying: "These specifications have been prepared: why do you not follow them?"

MR. SAWIN: There seems to be some special objection to the specifications, which, perhaps, is out of order, since there is no definite motion before us. In order to bring the subject definitely before the Section, I move you that these *revised* specifications be adopted with the usual procedure, which means, approved by the Technical Section and submitted to the Executive Committee for final action.

MR. R. D. COOMBS, New York City: Is Mr. Sawin not out of order? The only matter before the Section is the changes.

THE CHAIRMAN: I accept the correction and trust that Mr. Sawin will do so, as his motion has not been seconded. I will ask Mr. Paine to close.

Mr. Paine: As to sherardizing, the Committee made considerable effort to get proper specifications for this, but was not able to find any unanimity of expression which could be incorporated into a general specification. Any member having knowledge of the manner of testing or the manner of dealing with sherrardized material would render the Committee a great service by describing it.

The copper-clad cable unit stresses are included in the general application of the unit stresses applicable to the material employed. It has not been the practise of the Committee to incorporate any specification for one individual manufacturer's patented or copyrighted material.

A standard crossing specification is needed. There can be no question that the specification which will be followed by the company crossing must be, at least in a measure, satisfactory to the company crossed, and there must be a general agreement throughout the country. It is true, there is a great deal of construction in this country which does not come up literally to every detail of our crossing specifications; indeed, there is an enormous amount which does not come up to the specifications, and yet the work is very satisfactory. There has never been an instance within my knowledge when both parties have adopted the N. E. L. A. specification, where technical details, for some reason locally difficult to carry out, have not been waived if the crossing company properly discussed them with the railroad and telephone companies. Where, however, a railroad or telephone company has arbitrarily promulgated its own specifications, then trouble and expense are always found. This is a general specification with general application throughout the country, and should be followed. It is only fair that the company crossed should be protected.

Probably no one question has been more discussed than the limitation of 5000 volts in joint telephone and electric power work. Gentlemen, we all use telephones. Our children use them, our families use them. Our telephones must be safe. I do not know when or exactly how that limitation of 5000 volts will be raised. I hope it will be raised this year to 12,000 volts. I believe this will be accomplished, but until the telephone companies can provide a practical means of protecting their subscribers, and we are among the subscribers, we cannot afford,

for the sake of saving a few dollars at every crossing, i
please, to run the risk of injury to the community and tc
selves. I assure you that if properly applied these specific
are not arduous. They do not constitute an expense o
moment, and cause but little trouble. It is a worthy eff
make safe that other public utility which has the greater n
of people using it.

(Vice-President Abbott here took the chair.)

THE CHAIRMAN: The next number will be a pa
"Switchboard Instruments," by Mr. Paul MacGahan, of
burgh.

SWITCHBOARD INSTRUMENTS

The province of this paper is to cover in general both alternating-current and direct-current switchboard indicating instruments for the usual central-station or commercial service. The features of interest concerning both alternating-current and direct-current instruments will be taken up first; then novel features in each will be noted, followed by a brief description of the new forms of alternating-current relays.

The features of interest regarding instruments are as follows: Accuracy, compactness, reliability, damping, ruggedness, accessibility and simplicity.

Accuracy

High initial accuracy should not in itself be taken as a measure of excellence in a switchboard instrument, as reliability under operating conditions with a reasonable degree of accuracy is more important. A meter that may show an accuracy of ¼ per cent under laboratory conditions might be totally unsuited to the service intended. Assuming first-class workmanship and material, it is possible to obtain satisfactory initial accuracy with any modern make of instrument, properly applied. But continued accuracy under the varying conditions of operation is an entirely different matter and the purchaser who is governed by price and initial accuracy only, without regard to the principles of design or features of construction, is liable to get into difficulty later on.

What then are the features which should guide the purchaser in predetermining the probable operating accuracy of any given instrument?

The sources of error in any electrical instrument may be classified as being mechanical, electrical and observational. The electrical errors are, generally speaking, of less importance than the mechanical defects because the latter have an effect upon the life of the instrument and increase with time.

Electrical errors may consist of the following:

Temperature errors,
Self-heating errors,
External magnetic field errors,
Residual errors in direct-current moving iron meters,
Frequency errors in alternating-current meters,
Wave form errors in alternating-current meters,
Phase angle errors in alternating-current meters.

A careful study of the leading American makes of instruments shows that all are satisfactory for operating purposes, with regard to temperature, self heating, frequency and phase angle errors. There is a wide divergence as to action under the influence of external magnetic fields. Moving iron instruments show sufficient residual error to preclude their use for any service requiring accuracy on direct current. They also indicate incorrectly on rectified direct-current circuits because of wave form error.

The mechanical sources of error which may affect a continuation of accuracy are as follows:

Excessive weight of moving element,
Insufficient ruggedness of moving element,
Insufficient controlling force,
Insufficient insulation.

With regard to the weight of moving element it can be said that providing ruggedness is not sacrificed and a high ratio of torque to weight is maintained, the lighter the movement the greater the permanency. A movement which weighs ten grams is perfectly safe as far as jewel life is concerned, and one which weighs less than two grams is unnecessarily light; for if ruggedness is not sacrificed, as is usually the case in such light movements, the parts become too small to be handled or repaired outside of the factory. The following table gives the values of the weights of movement in the direct-current and alternating-current meters of three of the principal American makes together with the torque and ratio of torque to weight.

No.	Circuit	Type	Form	Grams Movement	Torque MM. Grs.	Ratio TW
1	D.-C.	D'Arsonval	9 in. am.	2.55	6.2	2.4*
2	"	"	9 in. am.	2.17	3.7	1.7*
3	"	"	9 in. volt	1.72	9.4	5.5*
4	"	"	9 in. volt	1.64	5.	3.0*
5	"	"	9 in. am.	2.7	9.1	3.4†
6	"	"	9 in. volt	2.4	12.	5.0†
7	A.-C.	Moving iron	horiz. Edge V.	9.	11.6	1.3
8	"	"	9 in. volt	1.91	.94	.5
9	"	Induction drum movement	9 in. volt	5.	15.	3.
10	"	Induction spiral disk movement	9 in. volt	21.7	20.	.93

* From reprint 163, Bulletin U. S. Bureau of Standards.
† Single Air Gap Type.

The figures given for alternating-current voltmeters are also approximately correct for ammeters and single-phase wattmeters. Corresponding polyphase wattmeters have movements which weigh twice as much and have twice the torque of the single-phase meters.

In order to reduce the errors of observation to a minimum the meters should have scales of maximum length compared with the space occupied on the switchboard; moreover the illumination of the dial and its legibility should not be interfered with by metal covers. A meter having a full glass front displaying the full length of the pointer is much more legible from a distance than one having a slotted metal cover.

Under many conditions of illumination it will be found to add considerably to clearness to have the dials a dull black with white markings and pointers. This also adds a certain elegance to the general appearance of the switchboard.

A comparison of legibility to switchboard space occupied was given in a paper by the writer read before the American Institute of Electrical Engineers in Boston, June, 1912, from which the following tables are reprinted.

COMPARISON OF VOLTMETER POINTER DEFLECTIONS

Rating	Size	Type	Point	Inches per Volt
150 volt	7½ in. round pattern,	induction type,	115 volt	0.16
" "	7½ in. " "	moving iron,	" "	0.035
" "	9½ in. " "	induction type,	" "	0.16
" "	9½ in. " "	moving iron,	" "	0.05
" "	9½ in. " "	D'Arsonval type,	" "	0.052
" "	6 x 8½ in. horizontal	edgewise, moving iron,	" "	0.023
" "	4 x 18 in. vertical edge,		" "	0.13

ALTERNATING-CURRENT INSTRUMENTS

Until recently the principal switchboard instrument construction comprised a case of circular form approximately 9½ inches in diameter. Attempts to economize space by reducing the diameter were not satisfactory, as they resulted in a considerable reduction of scale length. Edgewise construction of cases was often resorted to for economizing space at the expense of legibility. Complete and uniform lines of 7½-inch meters were not then available. More recently complete lines of alternating-current and direct-current switchboard round-type instruments in 7½-inch diameter cases have been brought out which have the same

scale length and clearness as the best instruments of $9\frac{1}{2}$ inch diameter. As the larger cases offer no advantage whatever over the $7\frac{1}{2}$-inch type, cost more, and require larger panels, the $7\frac{1}{2}$-inch form will in all probability be used to a greater extent in the future.

The induction principle of operation makes possible the successful $7\frac{1}{2}$-inch meter, as no other construction would result in a sufficiently long scale. Among the other advantages of this principle of operation are very high damping, comparative freedom from external field and temperature errors, and light-weight movements having simplicity and strength and a high ratio of torque to weight. The movements of the latest induction meters comprise an aluminum drum, shaft and pointer only, and weigh approximately five grams. No amount of shock due to overloads or rough handling in transit will injure such movements. The frequency errors are so slight as to be negligible for commercial switchboard service.

Polyphase wattmeters comprise two drums mounted on one shaft, each operating in the field of an independent electromagnet, thus having movements which weigh approximately twice as much as the ammeters and operating with twice the torque of the latter.

DIRECT-CURRENT INSTRUMENTS

The advantages of the permanent magnet or D'Arsonval meter for direct current are too well known to require description. The original double air-gap form of construction as found in nearly all the D'Arsonval meters is also well understood. A later development of the same principle is the single air-gap type having a coil pivoted at one edge, the opposite edge turning in a single air-gap. The purpose of this construction is to increase ruggedness, to permit removal of the moving element without disturbing the magnetic circuit, to allow magnetizing and ageing of the permanent magnets after they are assembled with the pole piece, and to lessen the reluctance of the magnetic circuit by reducing the air-gap to one-half the length of that used in the double-gap meters. Additional advantages are that this construction permits the use of a strong and clearly visible pointer, the coil being used to counterbalance the pointer, and that the possible scale length is greatly increased.

In the application of D'Arsonval meters to switchboards
rolling heavy currents, careful consideration must be given
:ray field conditions. If the meters are mounted in the neigh-
ιood of bus bars which normally carry heavy currents or
:h may carry heavy currents due to short circuits on the sys-
the result may be to permanently affect the strength of the
nets and thus the calibration.

In switchboard design it is generally feasible to keep the
zontal bus bars at a sufficient distance from the meters, but

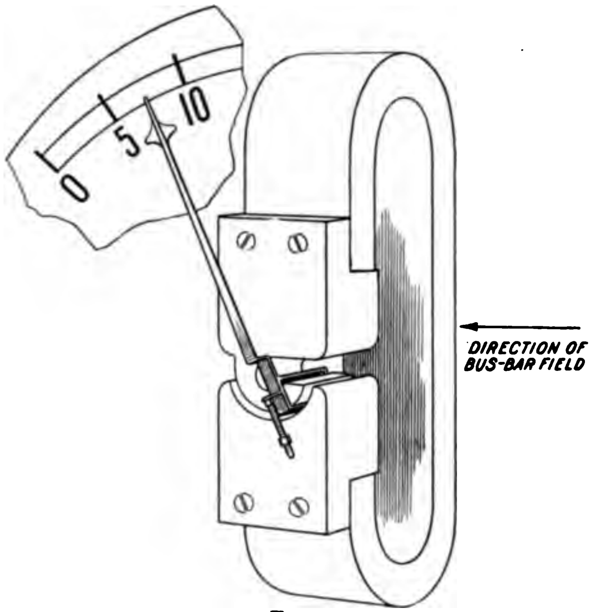


FIG. 1

often impracticable to keep the vertical or feeder bus bars
enough behind the feeder ammeters to avoid affecting the
nets.

Experiments prove that no reasonable amount of shielding
neans of thick iron cases or iron plates will prevent demag-
zation when short-circuits occur on heavy systems. Up to a
ιin point shielding is sufficient, but as the fields increase in
ısity the shielding material saturates and loses its further
:t entirely.

Thus two standard makes of D'Arsonval meters were placed inside of laminated iron ring punchings, forming a cylindrical wall around the meters 1½ in. thick, and 8 in. deep. The rings and the meters were placed in the center of magnetizing coils having 5000 ampere turns, so disposed as to correspond to the effect of stray fields from bus bars. A difference in reading of about 22 per cent was noted by reversing the current in the coil in both instruments and after the tests it was found that the strength of the magnets had been permanently reduced.

However, it was found that if the demagnetizing field is in such a position as to pass through the permanent magnets at right

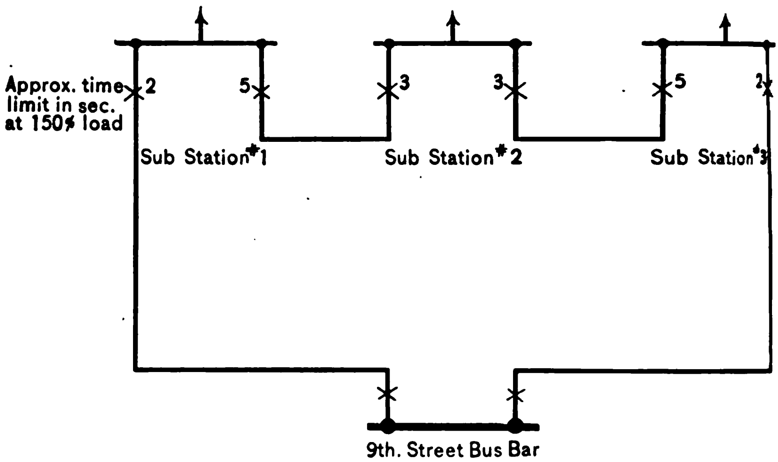


FIG. 2

angles to the direction of the permanent magnet flux—that is from side to side of the steel—there is little or no effect produced upon the magnet or upon the calibration of the meter. This is true even if the meter is entirely unshielded.

In the case of the single air-gap type meter it is perfectly feasible to so dispose the magnet that the stray field from a vertical bar will not affect the magnet. Fig. 1 shows the location of the bus bar and the direction of the magnetic field produced by it.

The use of meters with magnets especially arranged in this way is recommended for locations in proximity to vertical bus bars carrying heavy currents.

RELAYS

Closely allied to the design of the induction ammeters and wattmeters, is that of alternating-current protective relays. In these instruments the moving element consists of a circular disc, operating in the air gaps of an actuating electromagnet, and of a damping permanent magnet. The shaft instead of actuating a pointer moves a contact arm arranged to close a tripping circuit under predetermined conditions. The inverse time element characteristics are obtained by the action of the permanent magnet upon the disc.

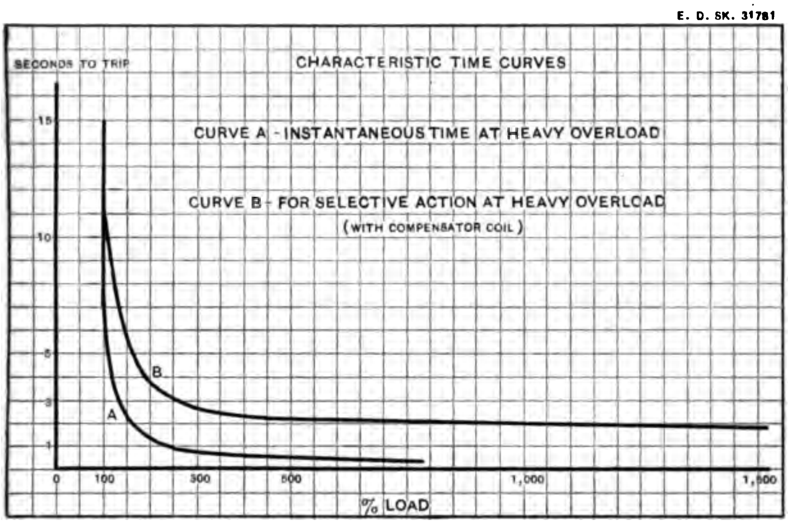


FIG. 3

These relays are made in the following types:

(a) Current or overload, inverse time element, operating instantaneously at heavy overloads.

(b) Current or overload inverse time element operating non-instantaneously at heavy overloads, the minimum time element for any overload being adjustable. The time curve characteristics of these two types are shown in Fig. 2.

(c) Overload and reverse relays, inverse time element. These relays will trip on heavy loads in the normal direction or light loads in the reverse direction providing the voltage or the power-

factor does not fall to a low value. At zero voltage or power-factor these relays act exactly like ordinary overload relays (a).

(d) Reverse current selective type relays. These relays operate on reverse currents exactly like relays (c) but have a selective wattmeter element in the same case so connected as to keep the trip circuit open whenever power flows in the normal direction, thus absolutely preventing the relay from tripping on overload, even should the voltage or power-factor fall sufficiently to make the true watts flowing in the normal direction as low as 2 per cent of normal full load value.

All of the relays mentioned are made in single-phase units two or more being required to properly protect a polyphase line. By means of relays (a) and (b) properly applied, complete selective protection can be obtained for radial feeders or tie lines operated in series.

Complete reverse current protection for generators, parallel feeders, etc., can be obtained by using relays (c) wherever the conditions are such that short-circuits or grounds will not cause a serious drop in the voltage or power-factor at the points where the relays are located.

It may be stated as an axiom or definite law that relays located at the substation terminals of transmission lines should be arranged so that tripping can never take place because of power flowing into the substation. Following this law, the reverse relays described completely solve the problems of reverse current protection, even in cases where voltage and power-factor drop to low value during short circuits. They are particularly useful at the incoming ends of transmission lines. In case of trouble on one line, the relay on this line will trip, due to the reversing of power direction, whereas, the relay on the other line will not operate no matter how great the overload may be.

These relays also furnish protection to ring systems of feeders. Let us consider two substations connected by transmission line with a set of these instruments at each end arranged to trip only when power flowing away from the substation exceeds a certain definite amount. Now in case of a ground or short between the stations, excessive power will flow away from each substation, both sets of relays will operate and the line is entirely cleared. Fig. 2 shows the actual arrangement of a disturbing system successfully using this form of protection.

DISCUSSION

MR. B H. SMITH, East Pittsburgh, Pa.: We have about 250 of these relays distributed among 25 operating companies, and so far as we know they are giving very satisfactory service. If any of the representatives of these companies are here who are familiar with these relays, we would like to hear from them.

MR. C. P. OSBORNE, Portland, Ore.: We have had occasion to try these relays in our part of the country, and we have found some of them satisfactory. I do not know that we have the particular type the gentleman speaks of. Most of ours are of General Electric make and I can say for them that usually—not always, but usually—they will do what we expect of them. One great fault with the alternating-current relay is its lack of accuracy. We cannot get one that we can absolutely depend upon. We have a good many of the bellows type of relay, made with a time limit, and while it is claimed they can be set to a definite limit, I disagree. We have not as yet had a relay from any manufacturer which is absolutely accurate as to time limit. If these are to be had now, it is time for us to bring our apparatus up to date. I simply want to state that I have supposed the different manufacturers knew that the relays are not reliable. We have not found them so.

MR. SMITH: I would like to say in regard to the accuracy of alternating-current induction relays, that we have known cases where a relay was correct every time tested within two cycles on 25-cycle work. An induction relay will give a much more accurate time limit than other types of relay, and for this reason we are laying special emphasis on this type. Possibly some time in the future we shall abandon the other type.

MR. MACGAHAN: I admit the defects in the bellows-type relays pointed out. Accuracy cannot be obtained with the solenoid type of bellows relay, due largely to depreciation of the leather in the bellows, and to the fact that this type depends for its time action upon the setting of a needle valve and the compression of the air.

The tendency in relays is to rely upon very great accuracy in the time set, more than in attempting to get accuracy in the load set. When you get a very heavy short-circuit actuating the relay at high overload it is much more important to have the timing predetermined correctly than it is to get the actual critical current-

trip value set right. For these reasons we have come to conclusion that further development cannot be expected with lows-type construction while the induction type will give required accuracy.

Actual tests show that the time element can be co upon to be correct at any predetermined overload, within tenth of a second with an induction relay. The resetting is so perfect that should the load decrease to normal at of a second before the relay contact has closed, the rela reset without closing the contact.

THE CHAIRMAN: The next paper will be, "The Developments in Distributing Transformers," by Mr. E. G. of Pittsburgh.

THE LATEST DEVELOPMENTS IN DISTRIBUTING TRANSFORMERS

INTRODUCTION

The most important recent improvements in distributing transformers have been in relation to the materials and methods of winding and insulating the coils. This has resulted in higher factors of safety between the actual disruptive strength of the insulation and the commercial tests applied. In some cases the commercial disruptive tests have actually been increased over those formerly used, due to the greater insulation strength secured, and the qualities of ruggedness, durability and safety in operation have been correspondingly enhanced. A further result of these improvements has been to increase the operating efficiency of the transformers.

The first part of this paper discusses these superior insulating materials and the scientific methods used in their application, particularly to the standard lines of 2200-volt distributing transformers. A cut of a typical transformer of this class is shown in Fig. 1. The second part of the paper relates to the improvements in performance which these materials and processes have made possible.

THE GENERAL PROBLEM OF INSULATION

The insulation of a transformer consists of three main parts, as follows:

1 Between turns and layers of the winding

2 Between the high and low-tension windings

3 Between the windings and metallic parts of the transformer.

Since the insulation of a transformer is no stronger than its weakest part, its various elements must be considered in their relation to each other. In other words, the factor of safety between the commercial tests applied and the ultimate strength of the various parts of the insulation should be consistent.

INSULATION BETWEEN TURNS

The amount of insulation which must be used between turns in a transformer winding is determined by the two following

requirements. First, the wires must have a coating of sufficie strength so that the mechanical stresses of winding will not c through and permit them to come into contact. The other requir ment is that sufficient dielectric strength be provided betwe the turns to withstand the electrical stresses which may occur the terminal ends of the windings during lightning disturbanc

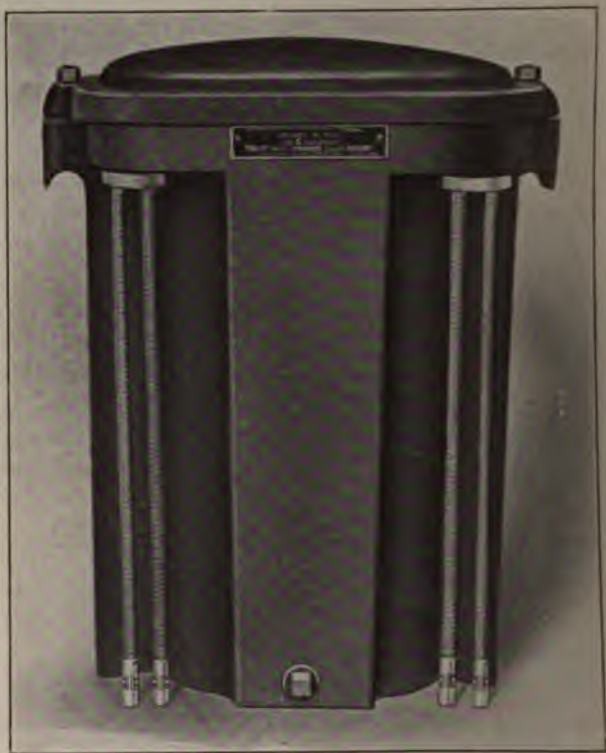


FIG. 1—TYPICAL DISTRIBUTING TRANSFORMER

The normal stresses between turns is of no importance, a average value does not exceed three or four volts. For conditions the merest mechanical separation of the wires w suffice without their being actually insulated. As a matte fact, it is practically impossible to obtain a commercial tes the transformer which will even approach the disruptive stre of the insulation between turns. An idea is obtained rel

to the difference between the normal voltage stresses per turn and the ultimate disruptive strength of the insulation, from the fact that the latter is usually several thousand times the former.

INSULATION BETWEEN LAYERS

The question of the insulation between layers of the winding is, in many respects, similar to that of the insulation between turns. In the winding of which there is one turn per layer, the stress conditions for turns and layers would be identical. In the ordinary winding, however, there are a number of turns per layer, in which case the layer stress becomes greater than that between turns. It thus becomes a matter of dividing the winding into a sufficient number of coils to keep the layer stress

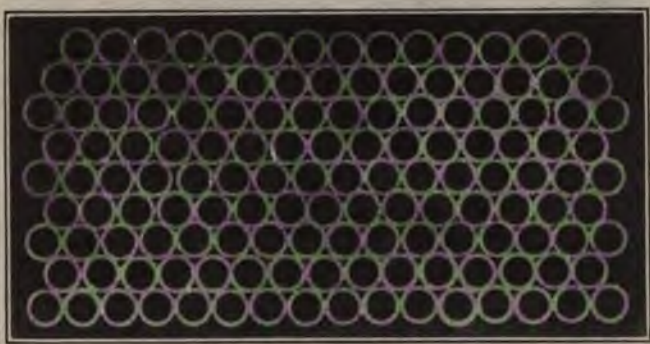


FIG. 2—GUTTERING OF THE WIRES IN THE MACHINE TYPE OF WINDING

to any prescribed value. If the layer stress is low enough, no insulating material is needed between layers, except that on the conductors themselves. In some cases additional layer insulation should be used between the layers adjacent to the high-tension outlet leads, in order to take care of lightning disturbances. With no material between layers other than a strip of cloth at the corners of rectangular windings which reinforces the insulation on the wires to take care of mechanical stresses, full advantage can be taken of machine winding. This style of winding possesses the advantage that the successive layers are guttered into each other and this takes up a minimum amount of

space. This guttering is shown in Fig. 2, and possesses other advantages aside from its economy of space. The interlocking of the layers prevents the crawling of one layer upon another,

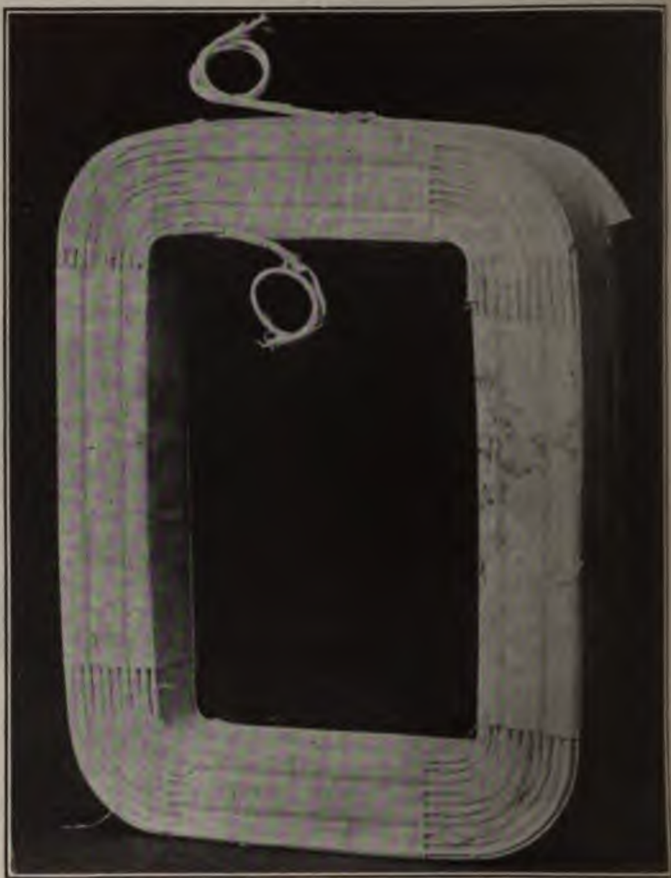


FIG. 3—MACHINE TYPE OF TRANSFORMER WINDING

during the heating and cooling of a transformer in service. This crawling of the layers upon each other in certain types of winding is a frequent cause of short-circuit. Further, the elimination of the layer insulation permits the heat to pass out of the coil with maximum efficiency. In a coil of this sort, impregnate

with a solid compound, almost ideal conditions for a transformer winding are obtained. In Fig. 3 is shown a photograph of a coil of the type just described. The winding is tied together by the strips of cloth at the corners, which lock the end turns of each layer in place. Similar strips of cloth are used on the four sides of the coil, each of which locks several layers together. In order to keep a factor of safety between layers commensurate with that between turns, the normal layer stress is made less than 100 volts. With a minimum ultimate disruptive strength between layers of several thousand volts, a large factor of safety is thus secured. This reduction of the normal stress between layers, secured by using a larger number of coils in the winding, has permitted the commercial over-potential test to be increased from three to four times the normal operating voltage. This testing stress is still not sufficient to approach the ultimate disruptive strength of the insulation between layers. The limiting value of the over-potential test is fixed by the stresses which are developed between the terminals of the winding and from the winding to ground. The excessive magnetizing currents which the transformer will take on such over-potential voltages is another limitation. As a matter of fact, an over-potential test of four times must be applied with a high-frequency current of something like 500 cycles per second to avoid prohibitive magnetizing currents.

A further advantage of this type of winding is the fact that the separate coils can be inspected before finally assembling into the complete transformer. Oil circulation is provided on each side of the high-tension winding and the coil is thin enough radially so that the temperature gradient between the windings and the oil will not exceed proper values.

INSULATION BETWEEN HIGH AND LOW-TENSION WINDINGS

The insulation between the high and low-tension windings should be a continuous insulating tube of high dielectric strength, which will take up a relatively small amount of space and which will maintain its dielectric strength after long periods at fairly high temperatures. Almost ideal tubes to meet these conditions are shown in Fig. 4. These tubes are made with a high grade of mica and imported Swedish paper, on machines specially constructed for this purpose. This formed insulating material is

called micarta—meaning better than mica. The paper reinforcing the mica imparts to the finished tube the mechanical characteristics which the plain mica lacks. The paper, which has been previously covered by a bond of shellac or bakelite, as the conditions may demand, is wound between steel rolls, under heat and pressure, on a steel mandrel. The bond is melted by the heat and the pressure between the rolls compresses the paper very solidly together. Built-up mica sheets are fed between the paper as it is wound on the mandrel, so that approximately 50 per cent of the solid finished tube is pure mica. In other words, 25 per cent of the total finished thickness of the tube is wound on the mandrel as paper, then 50 per cent of the thickness is fed in as mica and the remaining 25 per cent of paper goes on

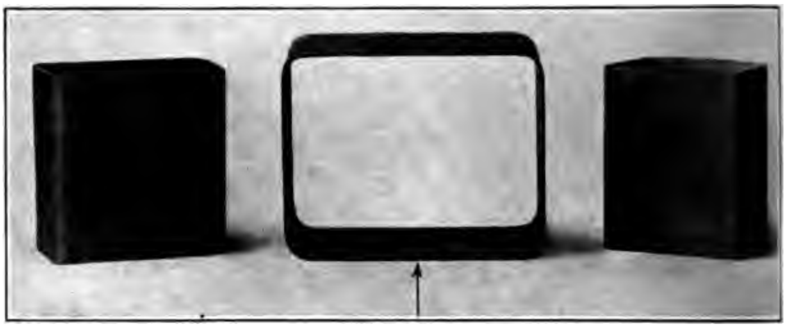


FIG. 4—MACHINE-FORMED INSULATING BARRIERS

the outside. By this method of manufacture a tube of maximum dielectric strength is provided for a given thickness. The tube is absolutely solid and of such a character that it will ring like metal when struck a sharp blow. The mica goes into the tube without wrinkles, which makes a uniform tube, without flaws. For those coils which are wound directly on the tube, the paper part of the barrier on each part of the mica protects the mica from mechanical stresses. This method of making these important barriers is a great improvement over the former method of winding the mica sheets between the coils by hand. This was accomplished by wrapping by hand the sheets of mica on top of one winding when it was on the mould and then winding another

coil directly on the mica sheets. It is impossible to wind the mica sheets by hand and prevent wrinkles. When a coil is wound over these wrinkles there is great likelihood of the mica in the barrier being broken through at these points. Further, coils wound on the soft mica, not reinforced, do not lie in smooth layers and the turns tend to lie over one another.

Fig. 5 shows a complete assembled winding for a small 2200-volt distributing transformer, having the machine-wound

FIG. 5—ASSEMBLED SET OF COILS FOR A SMALL 2200-VOLT DISTRIBUTING TRANSFORMER

type of coil and barriers between coils. Fig. 6 shows a similar set of coils pushed out endwise to show the arrangement of the coils and insulating barriers in their relation to each other. The general scheme of winding here described, where each part of the winding and the different insulating pieces are first made separately and then assembled, is striking in its contrast with the older forms of winding. With these older forms the complete

FIG. 6—SHOWING RELATIVE POSITION OF COILS AND INSULATING TUBES

FIG. 7—SHOWING PARTLY TAPED HIGH-TENSION COIL WITH INSULATING CHANNELS

il or group of coils was wound on one mould or wound directly the iron. With the improved type there is an absence of the ags and tags", which go with the older forms of winding that very pleasing and effective. Each part of the insulation in the proved method of winding has its place and is made exactly to nensions.

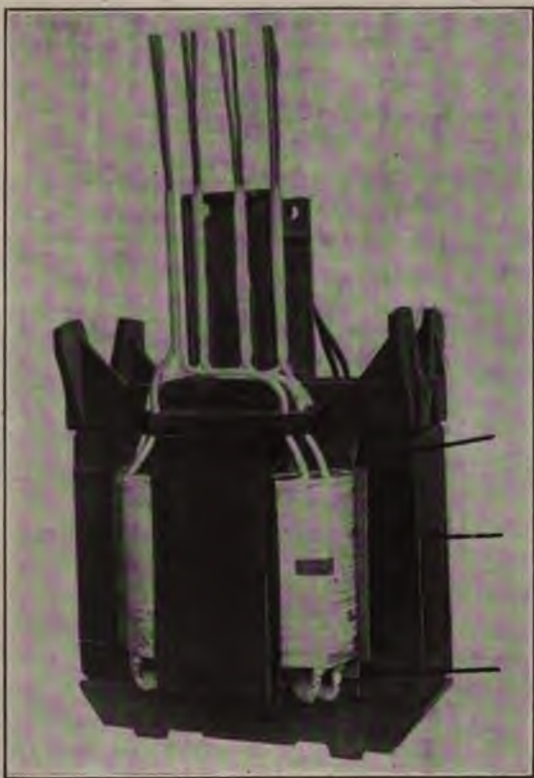


FIG. 8—SHOWING EXTERNAL INSULATING CHANNEL BETWEEN WINDING AND IRON

The requirements of the National Board of Fire Under-iters are for a test of 10,000 volts between the high-tension and w-tension winding, with the low-tension winding connected to e magnetic circuit and ground. The factor of safety for this rticular test has been made so large that it has been found

possible to make the test without submerging the transformer in oil. Oil submersion is used when the transformers are operating in service. The factor of safety of the barriers between the high and low-tension windings is so large that a direct puncture during tests never occurs. The barriers have a disruptive strength of approximately 75,000 volts. This value is determined by testing the barriers when separated from the transformer windings. It is necessary to submerge the barriers under oil for this test, as in air the discharge will usually flash around the edges before a direct puncture occurs.

INSULATION FROM WINDINGS TO GROUND

The insulation strength of the high-tension winding direct to ground must be as strong as that from the high-tension to the low-tension winding. This is accomplished by using a micarta

FIG. 9—SHOWING SEPARATE CHANNELS USED BETWEEN THE WINDINGS AND MAGNETIC CIRCUIT

channel over the ends of the high-tension coils where they pass under the iron. These channels are used only for the end coils, as the high-tension winding is concentric with and between the two parts of the low-tension winding. The channels are shown in Fig. 7, the taping having been partly removed from the coil so as to expose them. One of the channels is shown apart from the coil, to indicate its exact shape and purpose. In addition to the micarta channels on the ends of the high-tension coils the whole assembled group of high-tension and low-tension coils, is protected from the iron of the magnetic circuit on the ends by the channels shown in place in Fig. 8. These channels are shown separately in Fig. 9.

The failures which occur during test are always between the high and low-tension leads outside of the coil, or between

the high and low-tension leads and the ground. With the transformer submerged in oil the disruptive value at these points is something like 30,000 volts, varying with the different sizes of transformers.

The insulation from the inner low-tension winding to the ground is secured by the use of a machine-formed tube, made without mica, which encloses the middle leg of the magnetic circuit. These tubes are shown in Fig. 4. The former method of making this tube was to wind strips of paper around the mould and then the low-tension coil upon this hand-formed tube. With this method of manufacture it was difficult to avoid wrinkles and flaws.

OIL CIRCULATION FOR COOLING

The size and position of the oil ducts through the windings of a transformer have an important bearing on the merit and economy of the design. Sufficient oil-circulating ducts should be provided to limit the temperature gradient between the windings and the oil to approximately 10 degrees centigrade. This is not so much to obtain a safe temperature in the windings when operating at an average load, as to obtain a safe temperature on heavy loads. Rather extreme overloads for short periods are normal conditions for transformers of this type. The fact that the temperature gradient on overloads increases as the square of the load indicates the importance of a fairly low temperature gradient at normal loads. A lower temperature gradient than something like 10 degrees centigrade usually indicates that the materials in the transformer have been utilized rather inefficiently. In this case, if part of the ducts be eliminated and the space be given up to larger conductors, a lower copper loss results without exceeding safe temperatures at overloads. For the smaller sizes of transformers sufficient oil circulation can be secured by placing the ducts at the corners of the coils only. Such ducts are shown in Fig. 5, and are efficient for the following reasons: The size of the ducts which can thus be obtained is large enough to circulate sufficient oil to cool the windings, and ducts in the sides of the winding are not as effective as those placed at the corners. The return parts of the magnetic circuit interfere with the free circulation of the oil through all but the corner ducts, and thus reduce their efficiency. The use of ducts

under these parts of the magnetic circuit is, of course, beneficial due, partly to their tendency to increase the volume of the corner ducts, and partly to the circulation, although imperfect, of oil

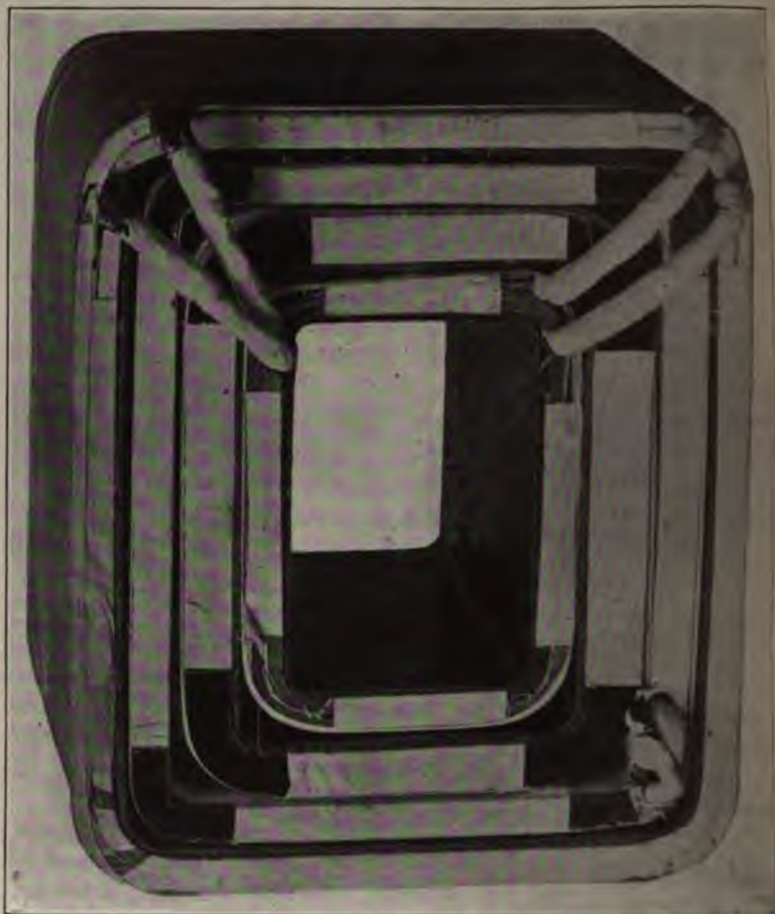


FIG. 10—CORNER OIL-CIRCULATING DUCTS

through them. With fairly large transformers where more oil circulation is required, an increased number of corner ducts are used as well as open side ducts. Fig. 10 gives an idea of this type of winding. For the largest sizes of distributing trans-

formers which require quite extensive oil circulation, the following arrangement of ducts is used and gives very good results. The smaller magnetic circuits on the ends of the coils contain only 25 per cent of the total weight of iron in the transformer. Therefore, comparatively large ducts can be provided in the parts of the coil embraced by these circuits and better cooling effect secured than with the same volume of duct extending uniformly around the winding.

These matters have been discussed not entirely because of their intrinsic value, but partly to show the care with which the details of the whole matter of design and proportion are considered for the best types of distributing transformers.

IMPROVEMENTS IN EFFICIENCY

The reduction in losses which has been made in 2200-volt distributing transformers is shown in the following table (page 622). While the actual reduction is not large, either in wattage or as a percentage, it must be remembered that the losses were already very low. The relation between the losses of a transformer and the amount of material used is such that a reduction in the loss requires a relatively larger increase in the weight of iron and copper, other things being equal.

SUMMARY

The important points brought out in this paper are the facts that improved methods of winding and insulating have resulted in better space factors in the winding, thereby permitting more copper to be put into a given space. This has given lower iron and copper losses, and at the same time the insulation has been improved. The improved insulation has, in turn, permitted an increase in the values of the commercial tests used. It also results in increased reliability and makes for long life and low depreciation of the transformers. These improvements, in the main, resulted from the guttered winding going with the machine type of coil, the use of improved machine-formed insulating barriers, and the arrangement of the oil-circulating ducts.

TABLE SHOWING REDUCTION OF TRANSFORMER LOSSES

Kva.	Watts Iron Loss		Watts Copper Loss		Percentage Exciting Current	
	Former Design	New Design	Former Design	New Design	Former Design	New Design
1½	25	24	35	33	4.0	4.0
2	30	29	42	40	3.6	3.6
2½	33	32	51	51	3.3	3.3
3	34	33	64	57	3.0	3.0
4	40	37	73	70	2.5	1.9
5	45	43	93	82	2.3	1.8
7½	62	57	125	110	2.2	1.7
10	80	70	148	140	1.9	1.65
15	105	95	212	192	1.6	1.5
20	131	123	268	255	1.5	1.3
25	147	135	319	305	1.3	1.25
30	163	158	374	370	1.2	1.15
37½	197	173	433	415	1.2	1.05
50	240	239	550	520	1.0	1.0

Further improvements are more likely to relate to the magnetic circuit than to the current-carrying circuit. The most probable improvement in the magnetic circuit lies in reducing the loss in the iron. This must be accompanied by an improvement in its permeability so that the reduction in loss could be utilized most economically. Such a reduction of loss would mean an increase of the magnetic density. This is at present impracticable, due to the rather low permeability of the iron and the increased slope of the magnetization curve at high densities. The influence of the gaps in the magnetic circuit on the magnetizing current of the transformer is a constant quantity and a fairly small one. By the proper location of the gaps in the iron and the proportioning of their area relative to the other parts of the magnetic circuit, the effect of the gaps on the magnetizing current of the transformer can be reduced to a fairly small percentage.

DISCUSSION.

MR. A. D. FISHEL, Pittsburgh, Pa.: I think an important feature of this paper is the showing of care used in the selection of materials and in the methods of construction and manufacture, all of which affect the life of such a transformer. We consider the transformer described in the paper as one of relatively good electrical performance, so that there should be no necessity to discard it for one of better efficiency for 10, 20 or 30 years,

unless it should fail in service, or the insulation deteriorate with time. We have given especial attention, as I have said, to methods of construction and the use of such materials as will ensure long average life, a characteristic that will, no doubt, be considered in connection with a great deal of other electrical apparatus in the near future.

THE CHAIRMAN: The next paper, Telephonic Communication The Means of Control for Central Stations, has been prepared by Mr. Angus S. Hibbard, of the American Telephone and Telegraph Co., New York City. Mr. Hibbard is unable to be here, and the paper will be presented by Mr. W. R. Abbott, of Chicago.

MR. W. R. ABBOTT, Chicago: Mr. Chairman and Gentlemen: Mr. Hibbard is unavoidably kept in New York by some illness in his family and has asked me to come over here to present this matter and discuss it with you. He has prepared a very interesting paper showing the value of telephonic control for central-station operation, and I will read parts of it.

TELEPHONIC COMMUNICATION THE MEANS OF CONTROL FOR CENTRAL STATIONS

Where one brain and one pair of hands best fitted to any task may be put in control of all its elements, we may look for the most highly finished product. In science, in the arts, in literature or invention, the best things have nearly always been those accomplished by some one individual. Such personal accomplishments may represent an ideal in quality, but this ideal cannot well apply in quantitative undertakings involving a large number of people or elements, and the man who thinks he knows it all and tries to do it all is rarely successful or popular in matters of any considerable size. Organized effort, however, shows its appreciation of the personal ideal by endeavoring to set up conditions whereby some one master mind at the top may give out the plan and policy to be pursued, and, through established channels, direct the efforts of all concerned. The same thing is true down the line where heads of departments and sub-departments, all interrelated, direct personally those things for which they are accountable.

It has been said that a business is at its very best when its purposes are best accomplished and the management has the least to do. Some one put it more tersely, saying: "If the bosses can ever truly say that they have nothing to do, it will be time to raise their salaries." Such statements, however, must be accompanied by equally convincing statements of conditions as they actually exist, and to state fully the condition of any business, there must be available full knowledge of just what is going on. In many businesses, information relating to existing conditions may be gathered more or less at leisure or as may best suit those who are in charge. A store may be closed to take inventory, or a factory shut down for some general overhauling. Both may control their methods and quantity of output, while the public, broadly speaking, is not affected. Not so are the public service businesses, the railways and carriers of all kinds, the water, gas, electric light and power companies, the telegraph or telephone companies, all of which must render service, not when and as they choose, but when, and, to a controlling extent, as their customers, the public, may choose.

Railways must provide trains at such times as people wish to travel—they cannot make them travel at times most efficient from the point of view of railway operations. Electric light, power and gas companies, telephone and telegraph companies must provide facilities to fit a load line, which is established by the public and is something over which the companies, themselves, have no control.

In the public service business, we have, therefore, conditions constantly changing because of demands which are practically uncontrollable, requiring not only the best kind of organization and management to insure success, but the best and most comprehensive means of knowing just what is going on, not from day to day, but constantly from minute to minute, during what may be called a continuous performance; and there can be no closing down for inventory, or repairs, or anything else. The wheels must continue to go round, and the public, without previous notice, determines just how fast they shall go. Under these inevitable circumstances, it may be said that the best service is rendered by those who keep in the closest and most necessary touch with the fluctuating conditions of this public demand, and in turn, have the best and most immediate control of the means of meeting it, so that, as nearly as possible, some one officer in charge may observe and direct operations.

All utilities are expected to be so designed that they may provide for average maximum demands for service. Probably no utility could be either well or profitably managed if designed to provide for the extreme possibilities of service. No railway, for example, could suddenly carry all the inhabitants of a large city at one time, or even in one day. In no telephone exchange could all of the subscribers talk at one time. Indeed, it has been said that if all telephone subscribers should call at once, everybody would get nobody, and nobody would get anybody. The average maximum demand, therefore, is studied and provided for; but even in this, not all utilities are affected alike in case of overload. In railway or street-car service, sudden emergencies are met by carrying as many passengers as possible, but the demands of those who are not carried may not seriously interfere with the successful transportation of those who are provided for. Sudden demands for gas are supplied from the storage reservoirs of gas companies, and, if not too long continued, may not interfere with

the general service. Sudden demands for telephone service, although complicated by the fact that two patrons instead of one enter into the problem of handling each telephone call, may be taken care of to the full limits of the system.

In electric light and power service the problem seems to be quite different, because in case of excessive overload the entire service is affected. In large communities it is the practise to provide a considerable margin of supply over and above the average maximum demand which may be reasonably anticipated, but in such a case if this maximum demand suddenly doubled, the system would break down and no service could be rendered to any patron. Moreover, electric light service seems to be subject to, perhaps, more sudden demands than other services. The load line running between minimum and maximum averages is, under normal conditions, fairly regular, but changing conditions bring about sudden and violent variations. A sudden storm, bringing about a temporary condition of partial darkness, may in ten minutes increase the lighting load 100 per cent, requiring the services of additional boilers, engines, dynamos, storage batteries, and all the sources of output, as well as a rearrangement of the facilities of distribution.

It is not surprising to find, therefore, that electric light and power companies, realizing these conditions, stand in the lead in providing unusual facilities for intercommunication and centralization of control, and, by extensive and well-engineered systems of telephones and supplementary appliances, have installed most efficient and up-to-date means of knowing just what is going on and for directing their service.

The time seems to have gone by when, even in small light and power installations, the management is satisfied to start up the machines and let them run along without regard to rate of use or volume of output. With the growth of these plants and the consequent need of greater efficiencies and economies, it has been necessary to secure more immediate and extended knowledge of operating conditions and a more centralized control, and these results have been obtained in the greatest degree where the best means of communication between all elements of the business have been supplied. An outline of what has been done by the lighting and power companies in a few of the larger cities will illustrate present conditions, showing the endeavor to centralize the

control of their great systems so that one brain and as nearly as possible one pair of hands, may best direct operations. As the relative capacities of the various plants are well known, they need not be referred to in detail.

In the City of New York, the two waterside plants of the New York Edison Co. constitute the producing center, at which an officer called the "System Operator" directs the operations of the entire system. It is his duty to keep in service at all times sufficient generating, transmission and transforming apparatus and to take care of any demand on the system, and no apparatus is put in or taken out of service except by his direction. He is provided with a telephone switchboard, from which lines run to 42 substations, also, trunk lines to the city exchange. The switchboard is ordinarily used by two operators (the equipment being in duplicate throughout), but is so arranged that during emergencies six operators are afforded facilities without interference. To this switchboard there are duplicate battery and signalling leads from two separate telephone exchanges. The building wiring is divided and led through separate building conduits to provide against local interruptions, and all of the substations are equipped not only with direct trunk lines from this operating center, but from the city exchanges, and the wires are led in through separate cables, and, where possible, from different streets, to avoid interruption from fire or other causes.

From this operating switchboard pneumatic tubes extend to the telephone switchboards at each of the Waterside Stations, and through these tubes all routine instructions of the System Operator at the switchboard are sent in writing, confirming telephone instructions.

Directly in front of this board and in full view of the System Operator is being installed the so-called "pilot board," designed to show automatically the operating conditions of the entire plant. At each end of this board, boiler and current recorders show the existing output of boilers and generators for the two stations. On the face of the board the districts of each of the substations are subdivided into small panels, indicating the oil-switches by numbers given to the feeder leads. The conditions throughout this distributing system are shown by small electric lamps. A red lamp lighted shows that a switch is closed, a green lamp lighted shows that a switch is open, and these lamps are controlled

automatically by the switches themselves. At each end of this pilot board the instruments which indicate at all times the total load carried by each station show how the load is divided as between 25-cycle and 60-cycle systems, the voltage and frequency of each system, and the current, if any, which is flowing from one station to another. In any emergency, therefore, by a glance at these instruments and the pilot board, the System Operator is as conversant with the conditions at each station as though he were standing before all of the switchboards at the same time. Consequently he is instantly in a position to direct by telephone the resumption of normal conditions without the delay heretofore necessary awaiting reports from switchboard operators as to their conditions, these conditions now being displayed automatically before him.

Previous to the use of the pilot board, the System Operator received all reports of outside conditions by telephone, and indicated operating conditions throughout the city by the use of colored tags, suitably numbered, and placed upon a large operating board representing the distributing system.

To still further safeguard the service during emergencies, the New York Company has installed a signalling system consisting of standard fire-alarm apparatus comprising circuits reaching substations, so arranged that the System Operator may send signals over all or any combination of the circuits at one time, such signals being recorded on paper tape and time stamped. For each signal there is provided a small brass wheel with notches corresponding to the signal number cut into its periphery. The signal numbers represent a predetermined code of instructions for this emergency service. For example, "2 2, trouble at Waterside; 2 4, system grounded, look over your apparatus and promptly report conditions to System Operator; 4 7, conditions normal; 6 6 (time signal). Correct time is 12 o'clock noon." This latter is used as a daily signal to test out the system, which, as indicated, is designed to care for unusual emergencies.

Adjacent to this signalling system is the city fire-alarm signalling apparatus, by means of which all alarms turned in on Manhattan Island are received by the System Operator. This apparatus was installed in connection with the city high-pressure pumping stations, current for which is supplied direct from the Waterside Plants. As these high-pressure stations use current

only when there is a fire, the System Operator, by receiving all fire alarms, knows just when the pumping motors may be expected to start, and is kept in touch with the situation during the progress of any fire.

Located at the side of the switchboard are boiler signalling switches, by means of which the System Operator signals to the boiler rooms the number of boilers required to carry the load. All routine communications between switchboards and the turbine rooms are carried on by means of lamp signals, and attention is called to them by means of electrically operated steam whistles. As weather conditions affect to a very large extent the demand on the stations, an outlook is stationed on the roof of the Waterside Building every day in the year except Sundays, with a direct telephone line to the System Operator, to report any unfavorable weather conditions.

During the winter months, the load of the Waterside Stations increases from 4 to 5 o'clock in the afternoon about 90,000 kw., or at the rate of 1500 kw. per minute, and during thunderstorms in summer it may increase 50,000 or 60,000 kw. in from five to ten minutes, or at the rate of 5000 to 12,000 kw. per minute. To take care of these peak loads, reserve boilers are carried under steam during the entire year.

When there are indications of a storm, the boiler rooms are signalled for the reserve boilers and additional turbines are started, connected to the bus-bars. During the approach of the storm, steam is shut off from these turbines and they are run as motors, in this way being available to take their share of the demand in about ten seconds. With the coming of partial darkness, the load advances so rapidly that it is practically impossible to so control the substations as to keep the load divided between the Waterside Stations as apportioned, and during such periods the flexibility of the system, due to the parallel operation of the two stations, is apparent, excessive loads of one station being relieved by the other. At times, from 10,000 to 20,000 kw. may be going from one station to another in one minute, and a few minutes later this condition may be entirely reversed. Successful operations under these extreme conditions is evidently made possible by the centralization of control which has been described, and this in turn is made possible by the systems of intercommunication which bring to the one official in charge knowledge

of what is going on and furnish the means of carrying out all possible directions.

In the switch-rooms of each of the waterside plants there are installed telephone switchboards, with lines extending to the board of the System Operator, the turbine-room, the exciter switchboard and the company's Operating Department branch exchange. There is also an intercommunicating telephone system with from 20 to 30 stations, located in various parts of the switchboard galleries. In each of the Waterside Stations, telautographs are also used between the high-tension switchboard and the exciter switchboard, so that instructions may be recorded. Here, again, we find that one directing head in each power station may control by telephone all parts of his plant as directed by the System Operator, the endeavor being to provide a completely centralized system of information and control. In the substations, telephone switchboards are located, connected by trunk lines with the switchboards of the System Operator, the Plant and Service Departments, the General Offices and the Telephone Exchange.

For the plant and service operations of the company, a 4-position switchboard is installed in the Supply Department, Forty-first Street, with 26 trunk lines connecting with telephone exchange, and 116 extensions and trunk lines reaching the general offices, the district headquarters, branch stations, contract offices, etc., there being 11 trunk lines to the general offices, 5 to the Second District, 2 to the Third, etc. None of these trunk lines or extensions are listed in the telephone directories, and it is not expected that the public, through the general telephone system, will at any time be brought into communication with the company through this system, which is provided for the exclusive use of the company's employees, upon its business between various offices and branches throughout the city, and for these purposes is carrying a traffic of about 5000 calls per day at the present time.

A special telephone directory is printed by the company giving locations and telephone numbers of offices and stations, and names and numbers of officials and departments, both for regular service, and for night, Sunday and holiday calls, the residence telephones being used to call out the forces at such times.

In Chicago, the Commonwealth Edison Co., in addition to a 12-position switchboard operated as a main exchange and con-

nected with all operating plants and branches of the company, has what is termed a Load Dispatcher's Board, with outside trunk lines and 80 terminals or extensions used for operating purposes, which gives the Load Dispatcher's office direct communication with all the power plants and distributing centers. Each of the large generating stations is provided with a switchboard with outside trunks and connecting trunks to the company's main switchboard, and terminal stations throughout the plant. In addition, each of the generating stations is provided with an intercommunicating telephone system reaching ten different points. The Load Dispatcher's switchboard of four positions is independent of the company's main switchboard, and as nearly as possible, wires to these boards and all others in substations or generating plants are conducted over separate routes to avoid interruption of service. These telephone facilities are supplemented by appliances indicating automatically at each station the output of the other stations, making possible, to a certain extent, the operation of different stations according to predetermined schedules.

In Boston the lighting and power system is controlled and centralized by means of a principal supervisory telephone exchange, with five tie-lines to the company's main exchange, two trunk lines to the South Exchange and 42 circuits to outside power plants. The company's principal exchange is a six-position switchboard, with 36 trunk lines and 193 stations, and in addition a special supervisory switchboard in the Commercial Department—an elaborate system for reaching customers and the general public.

In Philadelphia, Pittsburgh, Cincinnati, St. Louis and other cities, the lighting and power companies are utilizing telephone service in a like manner for centralizing information and controlling operations.

These telephone installations and the elaborate supplementary systems installed in a few of the larger cities certainly indicate the value of such service, and show particularly the advantage of separating from the service essential to the company's own operations, within itself, the public telephone service connected with customers and the general telephone exchange. The introduction of such special and separated service and its successful use over a considerable period seem to show that it is well worth while.

From the very nature of electric light service, it is essential that there should be means for the quickest kind of communication between the company and its customers, and the telephone is naturally used for that purpose. Here, again, it is interesting to find that the companies in many cities have specialized on the telephone and developed methods which not only increase the efficiency of their own service but which, to some extent, have been followed by other corporations, and might well be followed by all telephone users.

We find, in Chicago, in the offices of the Commonwealth Edison Co. a main private branch exchange of 12 operating positions, with 100 trunk lines and connecting trunks, and 475 terminals and extension telephones. Traffic reports show that about 17,000 messages are handled daily, or upwards of 5,000,000 calls each year. In connection with this main switchboard, there are two subsidiary boards in the Testing and Contract Departments, and also about 30 so-called key cabinets, or intercommunicating switches of from 2 to 10-line capacity, each used in lieu of a subsidiary switchboard, the principal installations being in Repair and Renewal Departments where a great many customers' calls are received by clerks trained for this purpose.

In the plans being made for the removal to another building of the general offices of the Commonwealth Co. in 1914, a 30-position telephone switchboard is provided for. In the commercial work of the company, telephones are provided for solicitors, the lines of which are connected to a monitor switchboard, so that, in the absence of a particular solicitor, the monitor board operator may answer calls, insuring prompt attention to the customer. Applications for electric service are accepted by telephone as a part of the regular commercial work. During 1912, 13,609 such applications were recorded, together with about 5500 orders regarding meter service. During the last five months of 1912, there were 8149 telephone inquiries regarding service and 12,672 requests for solicitors to call.

The above figures indicate the growing relations between the public and the company with regard to contracts for new service, as well as existing relations carried on by means of the telephone.

The Commonwealth Co. was, perhaps, one of the first to extend its telephone facilities largely into this public relation. The

second edition of its book of instructions, entitled "About Telephones," is dated November, 1911, and states that "The telephone, which was a relatively unimportant adjunct to our business 16 years ago, is now the principal medium of communication with our customers. . . . For this reason, it is a matter of the most vital importance that our telephone service, which we aim to make the best in the city, should be characterized by unfailing promptness, courtesy and accuracy." There follow brief instructions relating to promptness in answering calls, how to answer them, and inviting an avoidance of the word "hello." These, and various other points are further elaborated in the "Employees' Hand Book" of the Commonwealth Co., and the company's idea of the A B C of telephoning has been particularly indicated by an attachment to each telephone transmitter, to which, I feel sure, no telephone company will object, and upon which is printed, in large letters, the words, "ACCURACY, BREVITY, COURTESY."

The New York Edison Co. has also provided comprehensively for communication from and with the public, having installed in its general offices a private branch exchange with 51 trunk lines and 267 telephone instruments. There are, in addition, 19 private branch exchanges in various offices of the company throughout the city, having 79 trunk lines and 378 telephones. The full telephone equipment of the New York Co. at the present time is 24 branch exchanges, 750 telephone extensions, 161 trunk lines, 66 tie lines, connecting various switchboards of the company, 446 miles of telephone circuits, 25 direct exchange lines, and a traffic running about 20,000 calls per day.

The 1911 edition of the company's pamphlet concerning telephone service states: "A large part of our business is now transacted over the telephone. The public deals with us by telephone —we deal with ourselves by telephone. The telephone is the chief means of communication between our many departments and employees scattered over the city. Our commodity, electric current, is distributed by a system that resembles train dispatching, done over a special telephone system. Now, as the telephone is so very important to us, and becoming more so each year, we want to develop it as actively and intelligently as any other department of the Edison Service."

Several pages of interesting and valuable suggestions in regard to the use of telephones follow this introduction. One interesting rule is to the effect that no patron who is answered by a representative of the company shall be "switched," even if he has been connected with the wrong department, the rule being that the call will be attended to as far as possible and completely taken care of by the person who answers, without switching from one department to another.

It would probably be just as difficult to find an electric light or power company without a telephone as to find a telephone exchange without electric light where it is possible to get it. This reciprocity may also be stated in terms of bills paid for service, and in this, the two cities of New York and Chicago will be found to be fairly representative of the entire country. For the year 1912, the amount paid to the New York Edison Co. and the Commonwealth Edison Co. for service was $162,821. The amount paid by these companies for telephone service was $107,320.

The classes of customers of the two interests are very much alike, and the distributing plants for both services cover very nearly the same areas. It is natural, therefore, that the relations between the two interests should each year become reciprocal to an increasing extent. Joint pole lines for the distribution of wires have come into more general use. Construction details for necessary crossings and for paralleling routes are now generally matters of agreement between engineers. Telephone companies are relying on your services increasingly each year for power and light, finding with the growing stability of the plants less of a requirement for duplication in the way of local installations.

For both services, lighting and telephone, so closely related and inter-dependent, I think it may be said that the officers in charge are endeavoring in the conduct of the business to serve the public efficiently in the spirit that they and all employees are directly accountable to the communities in which they operate for good and dependable results. The appreciation of these conditions by the public is indicated in the continued growth of the business. Both interests have been constant in the endeavor to increase the efficiencies of plant and organization, and have made this possible by highly developed systems of communication, as

a constant means of knowing what is going on and for the control of the services rendered.

Some one at some point put forth the undisputed maxim "Knowledge is power." In connection with the value to your business of this knowledge of what is going on, which I have endeavored to demonstrate, it seems fair to stretch the old maxim a little, and to say, in this case, that knowledge is not only "power" but "light" also.

DISCUSSION

THE CHAIRMAN: It is hard to decide which would be the worse off if a lighting company should shut off the power given to a telephone company or the telephone company should discontinue the service to the lighting company. In one sense I think the lighting company would suffer the most. It appears that two telephone companies paid the lighting companies $162,000 last year, and these same lighting companies paid the telephone companies $107,000. In that sense the lighting companies would suffer more than the others.

It has occurred to me, as it has at times to a great many others, that we could save a considerable amount of money by operating our own inter-departmental telephone system. Many lighting companies have included in their franchise the right to operate telephone wires. I presume that many other companies have tried that method as we have, in a way, and all that is needed is to try it for a while in order to go back contentedly to the old stand-by.

MR. A. L. LOIZEAUX, Baltimore: With reference to Mr. Abbott's last remark, it may be that in Baltimore we will change our opinion, but a few years ago, in order to dispense with the time required to get central from one station to communicate with another station, a telephone system was put in, connecting with all stations, so that the chief operator could talk to them all at once, or to anyone individually, calling them direct by means of a selector system, and, up to the present time, this has proved a great help to the service.

It is true that to maintain a private telephone system it is necessary to employ telephone wiremen, as the work is so totally different from lighting work, that men familiar with lighting

wiring may be useless on telephone work. There is no hardship, however, in keeping a few telephone men on the force, as they can do other work when they are not occupied on telephone work.

THE CHAIRMAN: The Commonwealth Edison Co. has a similar system, but it is maintained by the telephone company. What I meant was that it appears to be about as difficult for us to operate a telephone system successfully, as it does for a telephone company to do its own electric lighting. Will there be any further discussion? Mr. Abbott has something to offer, I think.

MR. ABBOTT: I think not, Mr. Chairman. I am very grateful to you for your courtesy and attention, and for the opportunity of being here.

(Adjourned.)

THIRD TECHNICAL SESSION

FRIDAY AFTERNOON, JUNE 6

THE CHAIRMAN, PRESIDENT TAIT: The opening number on the program for this afternoon is the Report of the Committee on Underground Construction, Mr. W. L. Abbott, Chairman.

REPORT OF THE COMMITTEE ON UNDERGROUND CONSTRUCTION

The report of the Committee on Underground Construction for this year deals exclusively with high tension transmission cables and discusses the subject under the following headings:

Periodic High-Potential Testing of Transmission Lines.
Carrying Capacity of Cables.
Graded Insulation.
Sector or Clover Leaf Conductor.
Current-Limiting Reactances.
Protection of Cables in Manholes.
Parallel Routes.
Trouble Reports.
Practical Hints.
Standard Form Paper-Insulated High-Tension Cable Specifications.
Specifications for Rubber-Insulated and Lead-Covered Cables for Operating Pressures in Excess of 2000 Volts.

The material for the report has been gathered from current engineering literature and from the experience of member companies, to whom the Committee makes acknowledgment for their liberal and valuable assistance. The answers received from member companies indicate a very wide divergence of policy in many important particulars, notably in the testing of transmission lines, the loading of cables and providing of parallel routes for transmission lines, and also in the opinions as to what should be put into and left out of cable specifications.

Last year the Committee submitted a suggestion for a standard form of specification for paper-insulated cable. This year the Committee, after considering criticisms which it had invited on last year's specification, has revised the specification to meet the ideas of the greatest number of the critics. It also submits for criticism the specification for rubber-insulated, high-tension cable, substantially as is used by at least two large companies, and on this last specification it particularly invites criticism.

In paper-insulated cable it appears that in some respects American manufacturers are behind European. In last year's

specification the bending test for cable was that the cable should be bent first in one direction and then in the opposite direction, twice repeated, to a radius of six times the diameter of the cable. The Committee is advised that American manufacturers consider this test too severe, although on European cables the same test is applied three times instead of twice. However, the specifications as here presented have increased the radius of bending to seven and one-half times the cable diameter.

In this report more space is given to the discussion of "Carrying Capacity of Cables" than to any other subject. Recommendation is made for very decided increase in rating during the winter season, and also that the current rating be varied inversely with the voltage on account of the heating in the insulation due to the leakage of current. One company suggested that the Committee include in its cable specifications a paragraph fixing the maximum temperature to which the cable should be worked and another paragraph limiting the allowable leakage of current through the insulation at that temperature. The Committee recognizes the importance of this suggestion, but is of the opinion that there is not yet available sufficient information to enable such specifications to be intelligently written. It is hoped that the discussion of the section on "Carrying Capacity of Cables" will help to clear up some of these obscure points.

Respectfully submitted,

Committee
W. L. ABBOTT, *Chairman*,
H. B. ALVERSON,
G. W. CATO,
L. L. ELDEN,
BURTON FRENCH,
S. J. LISBERGER,
E. B. MEYER,
PHILIP TORCHIO,
S. B. WAY,
J. B. NOE.

PERIODIC HIGH POTENTIAL TESTING OF TRANSMISSION LINES

There is a great variation of opinion in regard to the advisability of periodically testing transmission lines, the majority of the companies reporting that such tests are not applied.

Some companies subject their cables to a high-potential test once, twice and even three times a year, with pressures as high as three times normal working voltage. Other companies make insulation tests only, unless the record of any cable should show a gradual decrease in insulation resistance, in which case it would be subjected to a high potential test to break down the developing defect. Several cases of incipient trouble have been discovered and eliminated by this method, but it has not always proved successful.

One large company started to make high-potential tests on all of its cables twice a year, but for reasons this practice was soon abandoned. With the numerous changes in its underground system and the practise of subjecting cables to a high-potential test after any changes had been made on them, many of the lines thus obtained a test anyway; then a few cases occurred in which lines withstood the test but broke down shortly afterward, notably one case in which the lead sheath of the cable was damaged by electrolysis. This cable burned out a few days after the high-potential test, and an examination of the cable showed that there must have been a hole in the lead sheath for several weeks previous to the test.

Several companies are now installing apparatus with the view of making periodical high-potential breakdown tests on all of their transmission lines, while other companies which already have the necessary equipment have abandoned the practice of making such tests periodically.

In general, it might be said that high-potential tests increase the liability to subsequent breakdowns and often do not disclose existing points of weakness.

In order to obtain data on the practice of subjecting transmission lines to breakdown tests, both initial and periodic, and on their safe carrying capacities, questions on these subjects as given below were sent to various member companies.

The answers from twenty companies are given in the following tabulation:

QUESTIONS

High-Tension Cable Tests

1a—Do you subject your newly installed high tension cables to a breakdown test?

1b—If so, what is the test voltage in terms of the working voltage, and for how many minutes is it applied?

1c—After cables are put into service do you test them at regular intervals?

1d—If so, what intervals, what is the test voltage in terms of the working voltage, and for how many minutes is it applied?

rrying Capacity

2a—Of what kind of insulation, size of conductor, and for what voltage is the greater part of your high-tension cables?

2b—What do you consider to be the maximum safe carrying capacity in amperes per phase for continuous load?

2c—What is the maximum for one hour?

2d—Do you change your rating with the season of the year?

Following is the identity of the companies whose answers pear by number in the tabulation:

Company	
1	Commonwealth Edison Co.
2	New York Edison Co.
3	Edison Electric Illuminating Co. of Brooklyn
4	Detroit Edison Co.
5	Potomac Electric Power Co.
6	Rochester Railway & Light Co.
7	Fort Wayne & Northern Indiana Traction Co.
8	Kansas City Electric Light Co.
9	Des Moines Electric Co.
10	Toledo Railways and Light Co.
11	Duluth Edison Co.
12	Consolidated Gas, Electric Light & Power Co. of Baltimore
13	Union Gas & Electric Co., Cincinnati, O.
14	Edison Electric Illuminating Co. of Boston
15	Public Service Corporation of New Jersey, Newark, N. J.
16	The Milwaukee Electric Railway & Light Co.
17	Southern California Edison Co., Los Angeles, Cal.
18	Puget Sound Traction, Light & Power Co.
19	Duquesne Light Co., Pittsburgh, Pa.
20	Philadelphia Electric Co.

Company	1A	1B	1C	1D	2A*	2B	2C	2D
1	Yes	200%- 1 min.	No	....	Paper, 250-9	250 amps.	275 amps.	No
2	"	120%- 5 "	"	....	" 250-6.6	250 "	....	..
3	"	106%- 5 "	By megger	....	" 250-6.6	225 "	250 amps.	No
4	No	..	No	....	" No. 0-23	135 "	....	"
5	Yes	200%-10 "	Yes	Every other Sunday by megger	" 4/0-6.6	195 "	.....	"
6	No	..	..	....	" 250-11	200 "	250 amps.	Yes
7	Yes	225%- 5 "	Yes	3 times a year, double voltage	Cambric, 400-2.2	560 "	700 "	No
8	..	..	..	....	Paper, 3/0-6.6	170 "	200 "	Increase 25% in winter.
9	No	..	No	No	" No. 6-13.2	....	....	No
10	"	..	Yes	By galvanometer once a month	" -13	....	....	"
11	Yes	300%-30 "	..	....	Cambric, 4/0-4.2	200 amps.	200 amps.	"
12	"	225%- 5 "	Yes	Once a year 225%, 1 minute	Paper, 4/0-13.2	200 "	200 "	Reduce in summer
13	No	..	"	Twice a year d.c. insulation	" 2/0-4.5	140 "	175 "	Increase 10% to 15% in winter.
14	Yes	220%-30 "	By megger	Twice a year by Megger	" 4/0-15	210 "	250 "	No
15	"	200%- 5 "	No	No	" 2/0-13	175 "	190 "	"
16	Will	200%- 5 "	"	"	" No. 0-15	125 "	170 "	"
17	No	No	"	"	" 4/0-15	185 "	205 "	"
18	"	"	"	"	" 250-13	200 "	250 "	"
19	Yes	200%- 5 "	No	"	" 4/0-11	200 "	200 "	Increase 20% in winter
20	"	120%- 1 "	Yes	Once a year 120%, 1 minute	" 250-6.6	211 "	254 "	Reduce 10% in summer

*Circular mils and voltage in thousands.

CARRYING CAPACITY OF CABLES

The investment by member companies of this Association in isulated cables for the transmission of electrical energy at high oltages amounts to tens and perhaps hundreds of millions of ollars, and notwithstanding this enormous investment it does not ppear that a sufficiently complete investigation has ever been aade to determine the safe limits of loading under the various onditions to which such cables are subjected.

With a view to ascertaining the general practice and experince of member companies in regard to cable loading and cable ailures, there were included in a general letter of inquiry sent ut to 25 prominent member companies, questions relating to arrying capacity of cables. In answer to these inquiries 20 companies responded with answers relating to size of conductor, kind of insulation, voltage, maximum safe carrying capacity rating continuous and for one hour), and statements as to their pracice in changing the rating with the season of the year and as to whether or not they have ever had a cable injured from overload.

From these questions and answers it appears that with 13 of hese companies the only factor considered in fixing the permissile load is current density. Six companies make some slight difference in permissible load with the season of the year. None of the companies responding take the line voltage into consideraion in determining the load limitations of the cable, although one company calls attention to the fact that a high-tension cable is much more likely to reach dangerous temperatures on overload than a low-tension cable.

The carrying capacity of a cable is limited by the temperature of the insulation. This temperature may be so high that it will bring about the destruction of the insulation in a few minutes, or with a somewhat lower temperature the insulation will last for several hours or days, while with a still lower temperature it may have a life of several years, and with what might be termed moderate temperatures, no appreciable deterioration at all takes place.

Fig. 1 is a curve taken from the paper of Messrs. Steinmetz and Lamme, entitled "Temperature and Electrical Insulation," read at the mid-winter meeting of the A. I. E. E., from which curve it appears that paper insulation, as used on electrical apparatus, when subjected continuously to a temperature of 100 deg.

c., would have a life of 10 years, which means that such insı
would last 120 years if subjected to that high temperature
only one month out of each twelve; and, if during only
hours of each day of that month the temperature were hig
number of years over which the life of the insulation ex
would be proportionately increased. While this cannot be a
unqualifiedly to high-tension cable insulation, neverthel
permits of definite conclusions in regard to the destructive
of prolonged high temperature upon the life of high-tension
insulation. From the foregoing it also appears that in de

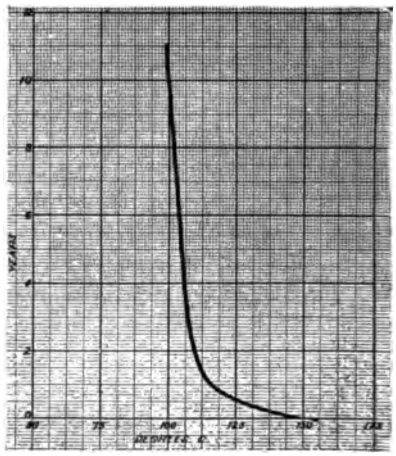


FIG. 1

what shall be the maximum load put on a cable of a
size, the economic questions of line load-factor and inte
investment should likewise be given consideration.

As the life of a cable varies in an inverse ratio w
temperature of its insulation, and as this temperature is a
by:

(a) Temperature of enclosed conductor,
(b) Temperature of surrounding air and objects,
(c) Heat generated in the insulation itself due to
leakage through the dielectric,

each is a factor which should be considered in determin
safe current load of a cable.

(a) *The temperature of the enclosed conductor* of course depends primarily on the temperature of the surrounding air, and in addition thereto, it has a temperature depending upon the square of the density of the current. Recent investigations conducted by Mr. L. L. Elden, of the Edison Electric Illuminating Co. of Boston, indicate that the average rise in the temperature of the lead sheath of 4/0, 3-conductor, 6000-volt cables, loaded for two hours to 210 amperes, is 15 deg. fahr., which would probably correspond to a conductor temperature of something less than 40 deg. above the temperature of the surrounding air.

(b) *The temperature of surrounding air and objects* in general varies with the season of the year and, of course, with

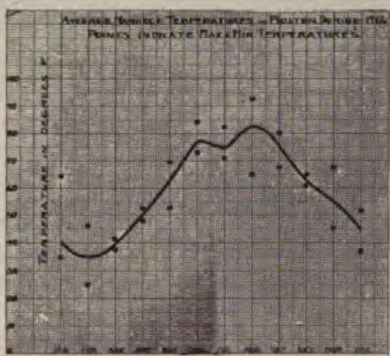


Fig. 2

the isothermal latitude; and, although such extreme variations in temperature are not encountered in subways as exist above ground, they, nevertheless, are very considerable, being affected doubtless by the kind of pavement and particularly by the sun's rays on manhole covers during hot days.

Fig. 2 is a curve plotted from temperature records taken by the Boston Edison Co., giving the average manhole temperatures during the year 1912, with points to indicate the maximum and minimum temperatures reached during each month. The minimum temperatures need not interest us, as it is only the maximum temperatures which limit the carrying capacity and which should be considered in fixing the safe loading of the cable.

Taking the highest temperature shown in the chart, 93 deg. [illegible] and comparing it with the highest temperature during the month of December, which is generally considered the month of highest load, we find a difference of 41 deg. This variation is as great as the rise in temperature which takes place under what most companies would consider the maximum loading, or, we will say a current density of one ampere per 1000 cm. It appears, therefore, that companies located in the isothermal latitude of Boston can load their cables in December for a temperature rise of 80 deg. as safely as they can load them for a temperature rise of 40 deg. in August, and to allow double the amount of heating would permit of 40 per cent increase in the current rating. This would warrant a current density of 1.4 amperes per 1000 cm. and would correspond to a load of nearly 300 amperes on a 4 0 cable, whereas only one company, it appears, would load a 4 0 cable up to 220 amperes in the winter.

With a ground temperature of 50 deg., the above loading would result in a conductor temperature of 130 deg. The conservatism of this rating is apparent when we consider that it is good practice in England to rate cables on the assumption that they will run at a temperature of 150 deg., and also, in view of the conclusions regarding heat-resisting qualities of insulation, which may be derived from the data submitted by Messrs. Steinmetz and Lamme:

(c) *Heat generated in the insulation by current leakage through the dielectric.*

Fig. 3 is a curve showing the relation between temperature and insulation resistance of a paper-insulated cable. The reduction in the strength of the insulation with the increased temperature is striking. Measured from 60 deg. fahr., the insulation resistance is less than half as great with each 10 deg. rise of temperature, the resistance at 100 deg. being only about 3 per cent of the resistance at 60 deg.; and when we consider that the amount of current escaping varies inversely with the resistance and that the resultant heating varies with the square of the current leakage, it is apparent that for any high voltage there exists a critical temperature at which the heating due to escaping current will be sufficient to carry the temperature up indefinitely or until the cable is destroyed. This heating due to escaping current is shown graphically in the curve, Fig. 4,

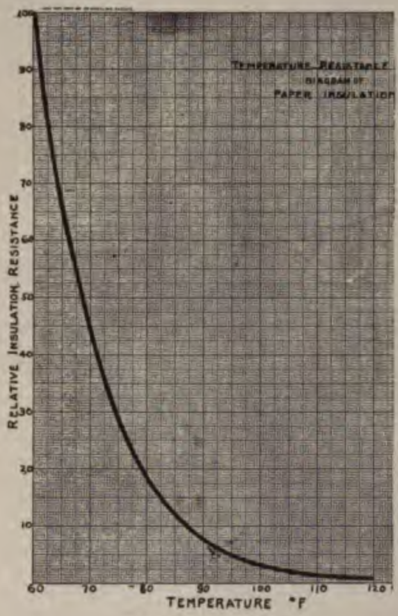
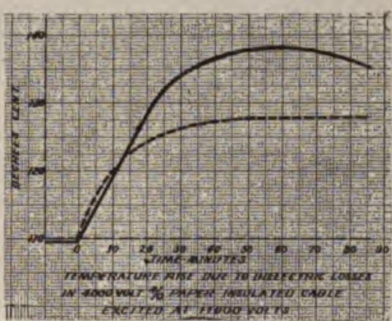


FIG. 3



—— Conductor
.... Lead Sheath

FIG. 4

which gives the results of a test made by Mr. E. O. Sch
of the Commonwealth Edison Co., in which a piece
single-conductor cable, insulated for 4000 volts, was pla
compartment having a temperature of 110 deg. cent., and
at 11,000 volts.

As shown by the curve, the temperature of the cable
increased above that of the air and the cable finally broke
a temperature somewhere near 140 deg. The curve shows a

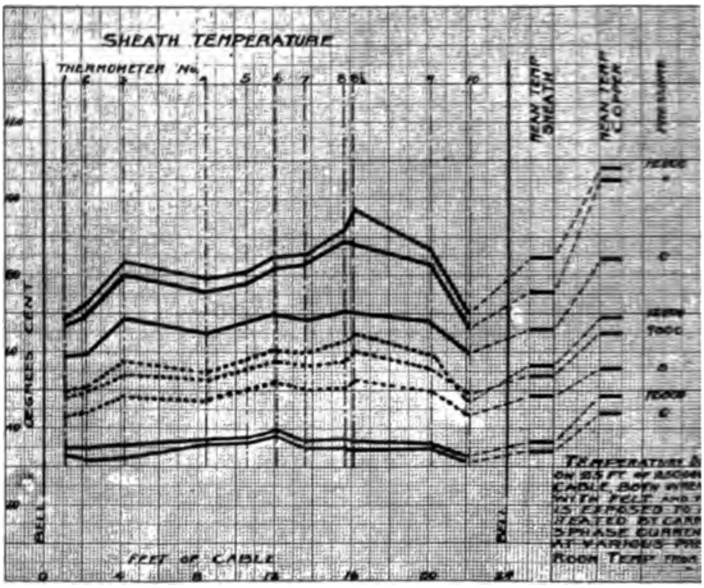


FIG. 5

iar drooping tendency above 130 deg. This is due to the f
the energizing current was supplied through current trans
of limited capacity, and as the insulation began to give wa
weakest spot, there was such a flow of current to that po
the voltage of the excitation current dropped, thus reduc
escape of current through the insulation in other parts
cable.

Fig. 5 shows the results of a number of tests with tw
of cable, through both of which a considerable ampere
was passed, and one of which was excited at 9000 volts and

lts. In each test the temperature due to the excitation above at due to the current alone is very noticeable, the increase being ughly between 30 and 40 per cent at 12,000 volts.

If the insulation of a cable is not of uniform resistance roughout the entire cable length, the weaker places in the insula- on will be subjected to the greatest heating from escaping cur- nts. This, in turn, will still further reduce the insulation resis- nce at that point, so that the breakdown, if any, will occur at ese initially weak points and probably before the insulation of ny other parts of the cable is at all injured. This is shown in urve No. 8 of Fig. 5, at the point where thermometer No. 8½ as located, which attains a temperature of more than 15 deg. bove the average of the rest of the cable; and from the appear- nce of the curve we might judge that had thermometer No. 8½ een located a foot or so farther to the right, a still higher tem- perature would have been recorded.

It does not appear that operating companies have experi- nced any considerable difficulty with the breaking down of cables perating below a voltage of 12,000, but as we get above that pressure and particularly around 20,000 volts, much trouble is experienced with insulation failure during warm weather; but when we consider that in spite of the thicker insulation for higher voltages, the heating at equal temperatures is almost in proportion to the square of the voltage and when we consider also n this connection the rapid decrease in insulation resistance ith increasing temperature, we can readily understand why the estructive action of high temperature and high voltage is so able to become "explosive" during extremely hot weather.

From the above discussion it appears that liability to cable breakdowns is a function of the temperature of the insulation, and this total temperature is the sum of three components—sur- rounding air, current density and impressed voltage. The temper- ature of the air in the subway may vary from 20 to 100 deg. fahr. The rise of temperature, due to such ampere loads as most com- panies carry, may amount to 40 deg., and in a 20,000-volt cable the rise of temperature due to current leakage at an initial tem- perature of 90 deg. fahr., may amount to 50 deg. fahr. as an average over the entire length of the cable. It appears, there- fore, that the greatest limitation to the current capacity of the cable is the varying temperature of the subway, and the next

greatest limitation in the case of 20,000-volt cables is the current leakage through the insulation, while the C^2R loss in the conductor itself is the lowest of all. It would, therefore, appear that if the rating of high-tension transmission lines were done more intelligently, greater consideration would be given to the temperature of the subway. The permissible load limits would be reduced during and following a hot spell and would be correspondingly increased during cold weather, which is the season when the maximum carrying capacity is most needed.

There is great reluctance on the part of operating men to run a cable at anywhere near the danger point, for fear that the insulation will be injured throughout the whole length of the cable; but from the evidence at hand this fear may be dismissed, for the reason that throughout a long cable and its many joints there exists one point where the insulation is weaker than at any other point and is much weaker than the general average of the remainder of the cable. In high-tension cables it is this weakest point which will be subjected to the overheating and will act as a safety valve for the entire line by "letting go" long before the rest of the cable has been heated to anywhere near the danger point.

The foregoing discussion is admittedly weak in corroborative evidence and scientific investigation, but the Committee believes that a lack of knowledge of the conditions contributing to cable breakdowns has led operating companies to apply a factor of safety to their cables, which has, in many instances, entailed an enormous investment in duplicate cables.

This Committee recommends that next year's Committee on Underground Construction have careful and elaborate tests made to determine the magnitude of the influences which have been herein referred to.

GRADED INSULATION

It is a well-known fact that the potential gradient of insulated wires is much higher in that portion of the insulation near the conductor than in the outer layers, and an equally well-known law that the fall of potential across a series of insulators of varying specific inductive capacities is inversely proportionate to those capacities. Cables insulated with two or more different materials so proportioned as to their relative thickness and specific

inductive capacities as to take advantage of these laws, have been on the market for some time, and it has been suggested that a similar "graded" insulation might be made up of paper alone, the grading being secured by saturating successive sections with oils so chosen as to give specific inductive capacities varying in the proper proportions. The advantages to be secured would be a smaller diameter of cable with the same factor of safety, or the possibility of producing a cable to operate at a higher voltage, the factor of safety and outside diameter remaining the same. The cost of manufacture of the cable with graded insulation would be somewhat higher, but, owing to the smaller amount of material required, the net cost would probably be somewhat reduced.

The possibilities of insulating a 2/0 B. & S. cable, with three layers of paper insulation having specific inductive capacities in the ratio of $K = 3$, $K = 2.5$ and $K = 2$ are illustrated by the accompanying curves, Fig. 6 showing the potential gradient under three different conditions. In each case the assumed test voltage producing the potential gradient is taken at 25,400 volts.

Case I. Conductor insulated with a single homogeneous dielectric 8/32 in. thick. The Curve A D J N P shows that the potential gradient decreases from 6500 volts per mm. at point A, next to copper, to 3000 volts per mm. at the sheath P.

Case II. Conductor insulated with three layers of materials having specific inductive capacities, K, in the ratio of 3, 2.5, and 2, their relative thicknesses being such that the maximum potential gradient is the same in each; the total wall being 8/32 in., as in Case I. The potential gradient in the inner layer is shown by the curve GK, in the middle layer by H L, and in the outer layer by I O, the maximum in each case being 4650 volts per mm., or only 71 per cent of the maximum in Case I. In other words, the cable could be operated at a voltage of 40 per cent higher than in Case I, the insulation being subjected to the same strain.

Case III. Reduce the total thickness of insulation until the inner layer is subjected to the same strain as in Case I, and so proportion the thickness of the same three insulating layers that each is subjected to the same maximum strain. The potential gradient in the inner layer is shown by the curve A D, in the middle layer by B E and in the outer layer by C F. The total thickness of insulation would be only 0.17 in., instead of 0.25 in.,

as in Case I and Case II. That is, we have reduced the thickness 32 per cent (the volume 50 per cent), and have the maximum strain the same as in Case I.

If it were possible to produce a perfectly graded cable, that is, one in which the potential gradient was exactly the same at every point between the conductor and the sheath, the necessary thickness of wall to give the same gradient of 6500 volts per mm.

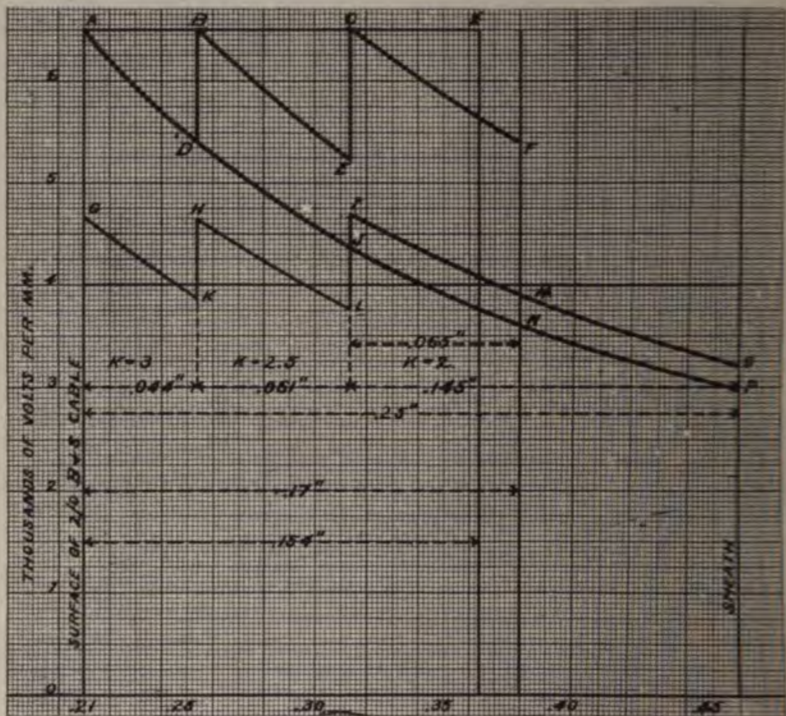


FIG. 6—DISTANCE FROM CENTER OF CONDUCTOR IN INCHES
POTENTIAL GRADIENT IN "GRADED INSULATION" ON 25,400 VOLTS

would be 0.154 in., and the potential gradient would be represented by the straight line A B C X.

In the above discussion it is assumed that the three layers have the same dielectric strength, otherwise we would have an unbalanced cable, and the weaker layer would puncture before the others were strained to the limit of their capacity. If

necessary, however, the condition of unequal strength could be taken care of by so proportioning the thickness of the several layers that each would be strained to the limit of its strength, instead of each being strained equally, as in the illustrations given.

The application of the principle of graded insulation to the production of a paper-insulated cable is dependent upon the practical consideration of securing commercial results by suitable processes of impregnation and manufacture. If this were practicable, and graded cables were developed by manufacturers, they would be assured of sufficient business to make the development attractive.

SECTOR OR CLOVER LEAF FORM OF CONDUCTOR FOR TRANSMISSION CABLES

With the increasing size of rotary converters and with the resulting increase in the size of the conductor in order that a line may have sufficient capacity for one converting unit, some of the member companies have reached the maximum size of three-conductor cables with round conductors that can be installed in a duct nominally 3 in. in diameter. To meet this condition and to make it possible to install cables of larger conductors or of thicker insulation, some manufacturers are making cables with the conductors in a clover leaf or sector form. To show graphically the advantages which may be obtained by the use of cables with such conductors, curves have been prepared making comparison between these two types of cables.

Fig. 7 shows the relative outside dimensions of cables of the round and sector types, the copper area and thickness of insulation being the same for each type.

Fig. 8 shows the increased wall of insulation which can be put on a cable of the sector type, the copper area and outside diameter being the same for each type.

In both of these curves the comparison is based on the round type of cable insulated for 6600 volts, that probably being the type in most common use by the member companies. For lighter walls the advantage of the sector type becomes more marked, while for heavier walls the advantage decreases.

For ordinary walls, the sector type of cable possesses no practical advantages for sizes of cable smaller than about 4/0

B. & S. Though the curves show a theoretical gain down to about 2/0 B. & S., this is offset by the practical difficulties met in attempting to keep the sector shape with the smaller conductors.

As to price, the sector type will be slightly cheaper in the sizes from 4/0 B. & S. up, owing to the decrease in quantity of material required. This decrease in price becomes greater as the size of the cable increases.

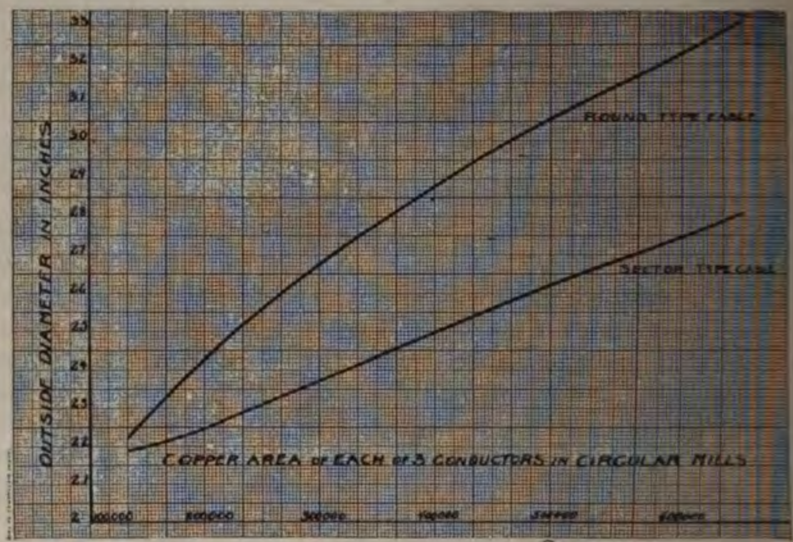


FIG. 7—OUTSIDE DIAMETER OF ROUND AND SECTOR TYPE CABLES HAVING 11/64 IN. INSULATION ON EACH CONDUCTOR, 5/32 IN. BELT AND 1/8 IN. LEAD

One member company has purchased and installed about 24 miles of three-conductor, 350,000 cm. 7/32 by 7/32 in. paper insulated cable of the sector type while another member company now has on order about 6 miles of three-conductor, 450,000 cm. 5/32 by 5/32 in. paper insulation. In either case it would have been impossible to install cable of the round type having the required copper cross-section and thickness of insulation in the existing subway system.

CURRENT-LIMITING REACTANCE COILS AND THE GROUPING OF FEEDERS

Nearly all of the large generating stations have their high-tension buses arranged so that all generators and feeders can be connected to either of two buses. The feeders are arranged in groups containing from two to five or six feeders each, all of the feeders of a group being connected to the same line bus.

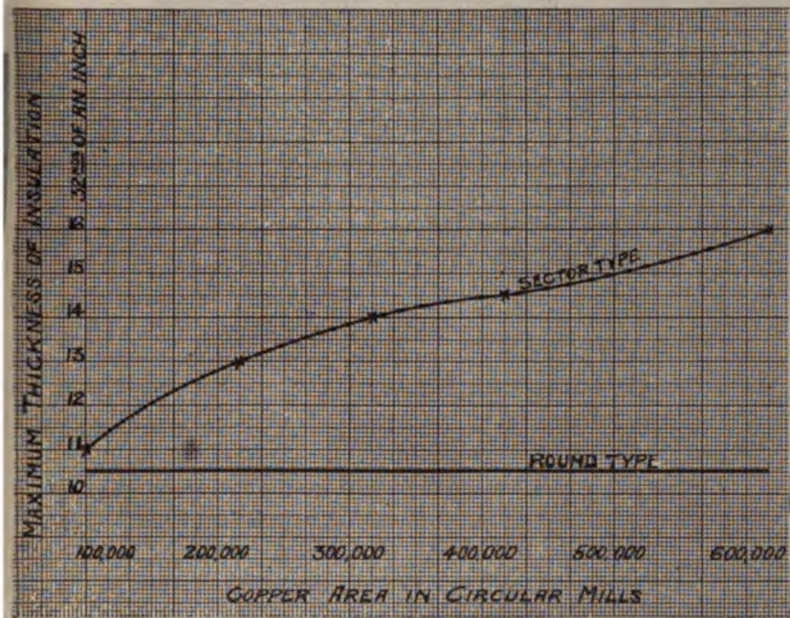


FIG. 8—INCREASE IN THICKNESS OF INSULATION POSSIBLE BY USING SECTOR INSTEAD OF ROUND CONDUCTORS, THE OUTSIDE DIAMETER AND COPPER AREA BEING THE SAME FOR EACH TYPE
INSULATION THICKNESS AROUND CONDUCTORS THE SAME AS OUTER BELT

Two group switches connect this line bus to either of the main buses.

All companies have automatically controlled switches on their high-tension feeders. In addition, some companies have their group switches controlled by automatic relays, so that in case of the failure of a feeder switch to open, there is the additional protection of an automatic group switch between the feeder in

trouble and the generator bus. Other companies have hand-controlled group switches exclusively, and during many years of operation have had no experience which would warrant them in installing automatic relays for controlling the group switches. When automatic relays are installed for controlling the group switches, it is very essential that they be installed and adjusted so as to secure selective action between the group switches and the feeder switches.

Several of the companies have step-up transformers interposed between the main bus and the line bus. Under these conditions all companies have automatic switches on the lines feeding the transformer. When transformers of large size with low reactance are used in this manner, it is customary to install a current-limiting reactance between the transformer primary terminals and the switch controlling the transformer. These reactance coils are for the purpose of limiting the amount of current which will flow in the transformer coils at the time of trouble on the high-tension lines which they feed and to prevent the mechanical injury to the transformer coils which is liable to occur in their absence. The amount of reactance required for this purpose should be sufficient to make the total reactance of the reactance coil and the transformer about 6 or 7 per cent at the rated full load of the transformer.

Where several transformers are connected in parallel between a high-tension bus and a low-tension bus, it has been found desirable to control the switches on the primary and secondary of the transformer by some form of balanced relay connection, so that the transformer will not be disconnected from either bus unless trouble occurs within the transformer. In such cases it is important that some indicating device be used which will immediately call attention to the fact that one transformer has been disconnected, in order that steps may be taken to prevent the overloading of the other transformers which remain in service.

Several of the larger companies have, within the past few years, installed current-limiting reactances on their generators or high-tension feeders. When the generating capacity connected to one bus exceeds, say, 50,000 kw., it will be found necessary to have current-limiting reactances on the generators, in order to prevent mechanical injury to the generator windings and buses at times of short circuits. One company has, in addition, found

expedient to divide its high-tension bus into several sections and connect these sections through current-limiting reactances.

At least one company has found it desirable to install such reactances on each of its high-tension feeders, and several other companies are contemplating the installation of similar reactances. All of these companies are operating an ungrounded system. None of the companies now operating a system with a grounded neutral are contemplating the installation of current-limiting reactances on their feeders.

Current-limiting reactances should be of the air-core type. Their capacity should correspond to the full-load capacity of the line or generator which they are intended to protect, and the reactance drop at full load should be approximately 4 or 5 per cent of the bus voltage. They are generally built with a core of non-magnetic material, such as wood, concrete, porcelain, or of several such materials in combination. In general, they are so bulky that it is difficult to find room for their installation in a station already built. In some cases separate structures adjacent to the generating station or the switch-house have been found necessary for their proper housing. When these reactance coils are properly constructed and placed, their installation involves no additional hazard.

PROTECTION OF CABLES IN MANHOLES

In order to prevent trouble on one cable from communicating to the other cables in the same manhole, the larger companies have found it desirable to cover their cables in manholes with some type of fire-proof covering. The principal types of protection used are as follows:

(1) Asbestos tape saturated with silicate of soda,
(2) Asbestos tape covered with a soft steel band armor,
(3) Split tile duct with cemented joints,
(4) A cement mortar coating with ¼ in. rope bond.

The two forms of asbestos tape covering have been in use for many years, and these types of protection appear to be entirely satisfactory to the companies using them. The split tile duct has in the past been used in large quantities by one of the member companies, but its use has been abandoned in favor of the cement mortar covering. Although tile is fire-proof in the ordinary sense, it will melt and flow in the case of a severe electric arc, and when

this occurs the cable is exposed to the arc which melted the tile. The tile is also injured by manhole explosions. It is difficult to cement the joints properly and also to carry the protection closely up to the mouth of the duct, so that there are, in general, a number of weak points in the covering in each manhole. In addition, there is considerable difficulty in a crowded manhole in tracing individual cables after all have been covered with tile. The increasing prices demanded by the tile manufacturers for the split tile duct in straight pieces and in bends were of considerable influence in the decision to abandon this type of covering.

The cement mortar coating is not affected by manhole explosions, and although the quality of the concrete and its strength may be seriously affected by the arc, it will in general remain in place and serve as a protection until it has been mechanically removed. The companies that have tried this type of protection are highly impressed with its value and freely recommend its adoption.

In determining the type of protection to be used, the heat resisting qualities of the covering are of more importance than the heat conducting qualities. Even when covered with the best non-conductor, the cables in the manholes will probably be cooler than the cables in the conduit. The type of covering used, therefore, has little if any influence on the carrying capacity of the cables.

The cost of protecting cables by the several methods described will, under ordinary circumstances, range between 20 and 30 cents per lineal foot of cable, except in the case of the unarmored asbestos tape, which is said to cost only 10 cents a foot.

PARALLEL ROUTES FOR TRANSMISSION LINES

Because of the liability of all of the cables in one conduit or in one street to be interrupted by accidents, an attempt is usually made in the important lines running from a power house to the same destination to route them in separate conduit lines or even in separate streets. Among some of the causes which might interrupt such lines are burning of cables by severe short circuits, caving of streets due to excavations for building foundations, sewers, subway construction, etc.; explosions due to illuminating gas; blasting or malicious mischief; washing out of pavement and conduits due to bursting of water mains; collapse of large building in case of fires; earthquakes or faulty construction.

While each of these possibilities constitutes an ever-present menace, the real danger of interruption of service to any line from these causes is quite remote and the warrantability of an increased investment to provide a duplicate route should be gauged accordingly. Some engineers are of the opinion that the greatest protection warrantable would be to provide duplicate routes in separate conduit lines in the same street. Others go to the extreme of providing a parallel route for the second line over streets which necessitate a much longer run than the original route.

Inquiries among a number of the leading companies show that some would not provide a duplicate route if it required any material increase in the length of the second line, while others, in special cases, would favor duplicate routing at an expense of 30 to 40 per cent additional.

Diagrams submitted by various companies show cases of duplicate routing, indicating that such duplicate routes could usually be obtained without increasing the length of the second line over 5 per cent. It is believed, however, that but few companies would authorize the expenditure for a separate conduit line for the purpose of getting a second line to a given destination over a different route if duct space is available in the existing conduit line. Moreover, to cite a concrete example, it should not be considered good engineering to choose the longer route in a case where it is necessary either to place both such lines in the same conduit length one block long or to route the second line around the three sides of the block, as the slight advantage of diversity in routing over this distance would rarely if ever balance the triple expense incidental to the longer route.

REPORT OF TROUBLE ON UNDERGROUND LINES

The replies from member companies indicate that only a few use a regular form for reporting such troubles, while the majority have their reports made largely in the form of a letter from the foremen. In order to secure comparative information it is recommended that member companies have their reports made in accordance with the attached form. This report has been drawn up from the various forms and suggestions which have been submitted, and will be found to cover all ordinary cases of trouble. Some of the companies may find it of advantage to have the

report made in card form for convenience in filing, and i
is done some reduction may be made in the size of the r
It is very desirable, however, that in entering the inform
under the headings "Location of fault" and "Probable ca
injury" the foremen should have the accompanying for
report at hand and make entries on the card under one o
several sub-headings given on the report form. The back o
report should be used for describing previous troubles on
same line or in the same conduit, which may possibly have
a bearing upon the fault, as well as other items of interest w
cannot be readily summarized.

FORM FOR REPORTING

NAME OF COMPANY

......................, 19....

REPORT OF HIGH TENSION FEEDER TROUBLE

Date............... Time........ Feeder No........ From........
To........... Size........ Operating voltage........ Frequency....
Insulating material...... Insulation thickness...... Condition..
Made by................. Installed, date........... by............
Length of underground portion.............ft., overhead............
First indication of trouble...
Nature of trouble................... Reported by...................
Trouble occurred during test.........., or, feeder in service.........
Previous to breakdown, load on feeder.......Max. air temperature...

LOCATION OF FAULT

Fault located by:	Fault located in:
Inspection	Manhole—in joint ....
Report of	in bend ....
Loop test	in straight length.
Fault detector	Duct........feet from duct
Cut and try.....No. of cuts.....	Repairs completed at ....
Time required to locate	Feeder ready for service at..
Section of conduit	Location of duct occupied...

PROBABLE CAUSE OF TROUBLE

(a) Mechanical injury:
1—Extraneous mechanical ....
2—Electrolysis ....
3—Sharp bend ....
4—Overheating ....
(5—Surge on system) ....
(b) Defect in cable:
1—Defective insulation ....
2—Defective sheath ....
3—Defective joint ....Made by ....
(c) Cause unknown ....
Resulting damage in conduit or manhole ....
" " " station or substation ....
Detail report of trouble of............................on cable No..

PRACTICAL HINTS

The installation of eyebolts in the walls of manholes opposite each run of ducts has been found by one company to be a eat convenience for pulling in cable.

For cleaning out ducts a spiral spring, slightly smaller than e duct made of ¼ or 3/16-in. wire with ⅝-in. pitch, and ving the first few turns tapered, is used to good advantage. hind the spring a brush it attached, and the whole thing is awn through the duct in the usual way by a rope.

Tags for identifying cable have been made of various metals most all of which, however, with their fastenings corrode in a ort time, and become illegible or fall off. A lead tag, on which s been stamped the identity of the cable, and tied to the cable ith a lead wire, will last longer than any other metal. These gs can be made of various shapes to identify the various classes cable installed in the manhole.

A very effective form of manhole guard has been developed y one company. This consists of an angle iron frame with gs to set down into the square opening of the manhole and revents passers-by from falling into the hole, yet readily permiting of the passing of materials down to the workmen in the hole. his frame cannot be upset, except by bending the angle iron, nd so will turn away any but a very heavy vehicle. When not n use it can be collapsed and folded into a compact bundle. Vhen the situation is such that this type of guard cannot be sed, as for example near a car track where the cars swing over e hole, a cover consisting of a channel iron frame surrounding stiff wire mesh is used. This sets into the manhole frame in lace of the cover, and will bear the weight of a man or a light ehicle.

The prompt installation of an emergency telephone at or ear the location where street repair gangs are working has been ound to be feasible and of very considerable service. When epairs are being made at night it is particularly valuable, as here are few telephones accessible between midnight and morning. This complete telephone set is mounted in a box, which is ocked for security when not in use, and is kept at some conenient point, with sufficient wire to reach to the top of a pole from he ground, and on call is sent out to the location of the trouble. Arrangements have been made with the telephone company

whereby upon notification they send out a repairman who connects up the instrument to the nearest line available and assigns a regular number to the instrument. This telephone set has been installed and put into service in a remote part of the city within two hours from the time the order was given to the telephone company.

Some saving is being made by the use of kerosene blow torches instead of gasolene torches, there being beside the considerable saving in cost of fuel the lessened liability to accident.

Electric drills for use on work in manholes have been found to be of considerable convenience and save a great deal of time.

PRACTICAL HINTS CONCERNING THE INSTALLATION OF CABLES IN SUBWAY SYSTEMS

Plans showing routes of cables, reel numbers, cross sections of duct runs with the duct to be occupied marked, should be prepared for the convenience and assistance of men delivering cable in streets and installing it in ducts.

When drawing in cable, the reel should, where possible, be located with reference to the ducts so that reverse bends in the cable will be avoided. Cable should be handled in such manner as to avoid kinks, sharp bends or scraping at the mouth of the duct.

The pulling rope should be attached to the cable by means of wire lacing in such a manner as to avoid damage to the lead sheath, and the lacing should be carried back a distance not less than 10 diameters of the cable. After the cable is drawn in, the ends should be carefully inspected to make sure that the seal has not been broken, and ends of cable in the manhole should be immediately laid on racks to avoid injury.

Records should be kept of each joint made, giving date and the name of the jointer.

Paper cable should not be handled while at a temperature lower than 30 deg. fahr., and if it is necessary to pull in cable during weather of a lower temperature, the cable should first be artificially warmed.

STANDARD FORM PAPER-INSULATED HIGH-TENSION CABLE SPECIFICATIONS

Condition of Service

The cable is to be used as a part of a three-phase, .. cycle, delta star-connected underground transmission system, the normal working voltage of which is ... volts between phases, the voltage as determined in accordance with American Institute of Electrical Engineers' standardization rules.

General

The cable shall be composed of three separately insulated stranded copper conductors, laid together and covered with a suitable sheath. All labor and material employed in the manufacture and installation shall be of the best quality, appropriate for the purpose intended, and shall conform to the following specifications:

The cable covered by these specifications shall be guaranteed by the manufacturer to be free from defects in workmanship and material, and the manufacturer shall replace, without cost to the purchaser, any cable which shall develop faults within a period of ..... years from date of installation, except in cases where it can be clearly shown that the fault resulted from external causes, such as mechanical injury, electrolysis or lightning.

Conductors

Each conductor shall consist of soft-drawn copper wires, free from splints, flaws, joints or defects of any kind, and having a conductivity not less than 98 per cent of that of pure annealed copper, as defined by the American Institute of Electrical Engineers' standardization rules. The conductors shall be concentrically stranded in reverse spiral layers, the strands being of wires sufficiently small to insure the required flexibility in the cable. The area of each conductor shall be .... circular mils, and shall be taken as the sum of the areas of the several wires forming the stranded conductors when measured at right angles to the axis of each wire.

Insulating Material

The insulating material shall be of the best Manila paper free from jute, wood fiber, or other foreign material. It shall be cut in strips and helically and evenly applied to the conductor

to a uniform thickness of .../32 in. After insulation the three conductors shall be laid together, with a uniform twist, having a pitch not exceeding 25 times the diameter of one conductor measured over the insulation. The interstices shall be filled with jute, so as to form a true firm cylinder without openings or air spaces, over which is to be applied a paper insulating jacket in the same manner, and of the same quality as specified for each conductor.

During the process of applying the paper insulation and the jute filler and immediately before the insulation is impregnated, the cable shall be subjected to such treatment as will insure the expulsion of all air and moisture, incident to which treatment the cable shall be impregnated with an insulating compound of low specific inductive capacity, guaranteed not to run appreciably and to retain its sticky adhesive qualities during the life of the cable, and also guaranteed not to develop any chemical action within itself or with any other component of the completed cable.

Lead Sheath

The insulated cable shall be covered with a commercially pure lead sheath, tightly and evenly applied, and having a thickness not less than .../32 in. The lead from which the sheath is formed shall be freshly mined and shall contain no scrap and shall be free from blow holes, cracks, scales or imperfections of any kind, and shall not, at any point, be less than 90 per cent of the specified thickness. The completed cable shall not exceed ...... inches in diameter.

Tests

The following electrical tests shall be made by the manufacturer at his works and without expense to the purchaser, the manufacturer supplying all necessary apparatus and the purchaser to have the privilege of being represented when these tests are conducted. The manufacturer shall furnish the purchaser with copies of data sheets showing the behavior of cable during these tests.

(a) Voltage Test. Each length of cable is to be tested with alternating current, having a frequency preferably the same as that of the system of which the cable is to be a part. The test voltage is to be applied between all three conductors and between conductors and lead sheath at a temperature of 150 deg. fahr. If the cable is to form part of a system having a permanently

grounded neutral, the neutral point of the test generator shall be connected to the cable sheath during the test. If the cable is to form part of a system with an ungrounded neutral, two tests shall be made, the first with conductor A, the second with conductor B, grounded to the cable sheath. The apparatus supplying the energy for the voltage test must have a kilovolt-ampere capacity at least four times the kilovolt-ampere capacity absorbed by the length under test, and in any event must be not less than 25 kilovolt-ampere capacity. The time of application of the test and test pressure shall be: Five minutes at a voltage having a peak value two and one-half times the peak value of the normal working pressure as determined by spark-gap in accordance with the A. I. E. E. standardization rules.

(b) Insulation Resistance Test. (1) An insulation resistance test shall be made immediately before and after the voltage test. (2) The measurement shall be made with a direct-current voltage of not less than 100 volts, the reading to be taken after one minute's electrification, and shall show no appreciable decrease in the value of the insulation resistance between the two successive measurements. Measurements shall be made between each conductor and each of the other two, and between each conductor and the lead sheath. Any section of cable which shows a marked variation from others of the same type manufactured at the same time shall be held for further examination and if such variations cannot be satisfactorily explained the section shall be rejected.

(c) Break-down Test. Samples from 10 to 25 ft. long and selected by the purchaser at random from any cable lengths shall not break down under five times the working pressure applied for five minutes between all three conductors and between conductors and lead sheath, after samples with ends sealed have remained at a temperature of 150 deg. fahr. for 100 hours in straight single lengths with axes inclined 15 degrees to the horizontal.

(d) Bending Test. A sample from any length of cable shall be bent around a cylinder having a diameter equal to fifteen times the outside diameter of the cable over the lead sheath, and then be straightened out. It shall then be bent in the opposite direction around the cylinder and straightened out. This operation shall be performed twice in succession, after which the cable shall be capable of withstanding a voltage test two and a half

times working pressure applied for a period of five minutes between the conductors and between the conductors and the lead sheath, and shall show no signs of mechanical or electrical injury when dissected.

Test After Installation

The cable shall be capable of withstanding twice normal working pressure applied between all three conductors and between conductors and lead sheath for a period of ten minutes after being drawn into the ducts and jointed. An insulation resistance test shall be made immediately before and after the break-down test, using the method specified under (b-2) above and the insulation resistance shall not be materially reduced as a result of this test.

SPECIFICATIONS FOR RUBBER-INSULATED AND LEAD-COVERED CABLE FOR OPERATING PRESSURES IN EXCESS OF 2000 VOLTS

Common Mechanical Specifications

1 Each conductor, except outer conductors of concentric cables, shall consist of *not less* than the following number of soft-drawn copper wires, free from splints, flaws or other defects, having at least 98 per cent of conductivity, based upon Matthiesen's standard (as printed in the Supplement to the Transactions of the A. I. E. E., October, 1912), concentrically stranded together in reverse spiral layers and having an aggregate cross-sectional area when measured at right angles to the axes of the individual wires at least equal to that corresponding to a specified size, viz.:

TABLE A

2	No. 4 B. & S. G. and smaller	One wire.
	No. 3 B. & S. G. to No. 2 B. & S. G.	Seven wires.
	No. 1 B. & S. G. to 4/0 B. & S. G.	Nineteen wires.
	250,000 C. M. to 500,000 C. M.	Thirty-seven wires.
	600,000 C. M. to 1,000,000 C. M.	Sixty-one wires.
	1,100,000 C. M. to 2,000,000 C. M.	Ninety-one wires.
	2,100,000 C. M. and larger	One hundred and twenty-seven wires.

Intermediate sizes take the stranding of the next larger listed size.

3 The sheath shall have an average thickness of not less than that indicated in attached tables and the minimum thickness shall in no place be less than 90 per cent of the required average thickness. The sheath shall consist of commercially pure lead without tin, and it shall be so pressed over the insulation as to

make a tight fit to the end that no voids or pockets between said sheath and insulation shall exist in the finished cable. In cables having a larger diameter overall than two inches, the sheath in addition to being made of commercially pure lead shall be of metal direct from the original smelter.

4 Conductors shall be properly tinned.

5 The insulating compound shall be made exclusively from pure, dry, raw, wild South American para rubber of best quality of the grade known as "fine"; solid waxy hydrocarbons, suitable mineral matter and sulphur.

6 It shall be properly and thoroughly vulcanized.

7 The vulcanized compound shall show on analysis freedom from all foreign organic or injurious mineral matter, not less than 30 nor more than 33 per cent of above specified rubber; not more than four per cent of solid waxy hydrocarbons; not more than one and five-tenths per cent of rubber resins; not more than seven-tenths per cent of free sulphur and not more than two and sixty-five hundredths per cent of total sulphur in any form.

8 The manufacturer shall submit to the company a method of procedure for chemical analysis of his compound for the guidance of the company's chemist, in order that intelligent comparisons may be made in the event of dispute between the manufacturer and the company.

9 The compound must be homogeneous in character, tough, elastic, adhere strongly to and be placed concentrically about the wire and in section as stripped from the wire must have a specific gravity of not less than one and seventy-five hundredths, as compared with distilled water at 60 deg. fahr.

10 A sample of the vulcanized compound, not less than four inches in length and of uniform cross-section shall be cut from the wire and marks placed on it two inches apart. The sample shall be stretched longitudinally at the rate of 12 in. per minute until the marks are six inches apart and then immediately released. One minute after such release the marks shall not be over two and one-half inches apart. The sample shall then be stretched until the marks are ten inches apart before breaking.

11 The compound shall have a tensile strength of not less than 1000 lb. per square inch, based on the original cross-section of the test piece before stretch.

12 The above mechanical tests shall be made at a temperature of not less than 50 deg. fahr.

13 Each and every length of conductor shall comply with the mechanical and electrical requirements indicated in the following tables B, C, and D. The tests at the works of the manufacturer shall be made when the conductor is covered with the vulcanized compound and before the application of any covering other than a non-waterproof tape.

14 Electrical tests at the factory on single-conductor cables shall be made after at least 12 hours' submersion in water and while still immersed. The insulation test shall follow the voltage test and shall be made with a battery of not less than 100 volts or more than 500 volts, and the reading shall be taken after one minute's electrification.

15 Samples of the above cables six feet in length taken from any reel of cable must show an ultimate dielectric strength capable of resisting the application of twice the voltage specified above for a period of five minutes without failure.

16 Insulation resistance and electrostatic capacity tests made (before and after voltage tests as per table B), and under equivalent temperature conditions, must not indicate fatigue or overstrain of dielectric.

TABLE B

VOLTAGE TESTS ON SINGLE CONDUCTOR CABLES INSULATED WITH HIGH TENSION RUBBER COMPOUND. DURATION OF TEST AT FACTORY 5 MINUTES; AFTER INSTALLATION 30 MINUTES. TESTS AT FACTORY AS PER TABLE; AFTER INSTALLATION AT TABLE VALUES FOR 5 MINUTES, THEN AT 80% FOR 25 MINUTES.

Size Conductor		Minimum Thickness of Insulation in Inches.							
		3/32	7/64	4/32	5/32	6/32	7/32	8/32	14/32
Stranded									
1,000,000	C.M.		6,000	8,000	12,000	16,000	19,000	22,000	30,000
750,000	"		6,000	8,000	12,000	16,000	19,000	22,000	30,000
500,000	"	5,000	7,000	9,000	13,000	16,000	19,000	22,000	30,000
350,000	"	5,000	7,000	9,000	13,000	16,000	19,000	22,000	30,000
4/0	A.W.G.	6,000	8,000	10,000	13,000	16,000	19,000	22,000	30,000
2/0	"	6,000	8,000	10.000	13,000	16,000	19,000	22,000	30,000
1/0	"	6,000	8,000	10,000	13,000	16,000	19,000	22,000	30,000
2	"	7,000	9,000	11,000	14,000	16,000	18,000	20,000	30,000
Solid									
4	A.W.G.	7,000	9,000	11,000	14,000	16,000	18,000	20,000	30,000
6	"	7.000	9,000	11,000	14,000	16,000	18,000	20,000	30,000

TABLE C

INSULATION TESTS ON SINGLE CONDUCTOR CABLES INSULATED WITH HIGH TENSION RUBBER COMPOUND. TESTS AT FACTORY AS PER TABLE; AFTER INSTALLATION 80% OF TABLE VALUES.

Minimum Megohms per Mile at 60 Deg. Fahr.

Size Conductor	Minimum Thickness of Insulation in Inches. 5/64	3/32	7/64	4/32	5/32	6/32	7/32	8/32	14/32
Stranded									
1,000,000 C.M.			300	340	420	490	560	630	
750,000 "			350	400	490	570	650	730	
500,000 "			410	460	570	660	750	830	
350,000 "			520	580	700	810	910	1,010	
4/0 A.W.G.		530	610	680	820	940	1,060	1,170	2,000
2/0 "		650	740	820	980	1,130	1,260	1,380	2,240
1/0 "		710	800	980	1,060	1,210	1,350	1,470	2,400
2 "		950	1,070	1,170	1,380	1,560	1,720	1,870	2,750
Solid									
4 A.W.G.		1,130	1,260	1,380	1,610	1,800	1,980	2,140	3,200
6 "		1,330	1,480	1,610	1,860	2,070	2,260	2,430	3,600
8 "		1,560	1,720	1,870	2,140	2,360	2,570	2,750	
10 "		1,810	1,990	2,150	2,440	2,680	2,890	3,000	
12 "	1,860	2,080	2,270	2,440	2,750	3,000	3,220	3,420	
14 "	2,120	2,360	2,560	2,740	3,060	3,320	3,550	3,750	

TABLE D

GENERAL DATA ON CABLES INSULATED WITH HIGH TENSION RUBBER COMPOUND IN GENERAL USE BY THE EDISON ELEC. ILL. CO. OF BOSTON

Size	Conductor		Rated Working Pressure AC. or DC.			Minimum Thickness Insulation Inches	Thickness Lead Sheath Inches
6	A.W.G.	Sing.	Cond.	5,000	volts	5/32	3/32
4	"	"	"	5,000	"	5/32	3/32
2	"	"	"	5,000	"	5/32	3/32
1/0	"	"	"	5,000	"	5/32	3/32
2/0	"	"	"	5,000	"	5/32	3/32
4/0	"	"	"	5,000	"	5/32	3/32
6	"	"	"	10,000	"	7/32	3/32
4	"	"	"	10,000	"	7/32	3/32
2	"	"	"	10,000	"	7/32	3/32
1/0	"	"	"	10,000	"	7/32	3/32
2/0	"	"	"	10,000	"	7/32	3/32
4/0	"	"	"	10,000	"	7/32	3/32
6	"	"	"	15,000	"	14/32	3/32
4	"	"	"	15,000	"	14/32	3/32
2	"	"	"	15,000	"	14/32	3/32
1/0	"	"	"	15,000	"	14/32	3/32
2/0	"	"	"	15,000	"	14/32	3/32

DISCUSSION

Mr. Charles W. Davis, Boston (submitted in writing):

The Report is so full of interesting matter and so excellent in the great majority of its recommendations and suggestions that I hesitate to make any extended comment upon the few smaller details which appear to be subject to possible improvement, for fear of seeming hypercritical. I trust my comments may not be thought as offered in that spirit.

Re page 643, paragraph 1:

The Committee is possibly unaware that a very careful investigation of conditions affecting the safe limits of loading of cables was begun by Mr. H. W. Fisher as early as 1890, culminating in the immensely useful results obtained in 1902 in Niagara Falls under actual working conditions, and, in more recent years, under various experimental conditions (see Standard Underground Cable Co.'s Handbook XVII or 1906, XV of 1897 and earlier; papers by Mr. H. W. Fisher alone and in collaboration with Mr. R. W. Atkinson, A. I. E. E. Proceedings, June, 1905, and Feb., 1913.

It is my opinion that the greatest impediment to a thorough understanding and acceptance of the laws controlling the safe limits of loading is the unwillingness of the cable user

at times to make use of the best data on this subject. The old rule of one ampere per 1000 cm. is clung to tenaciously in some quarters, although all experimental data on the subject show that, if it be a correct rule for one size of conductor under a given set of conditions, it cannot be even approximately true for a few sizes larger or smaller.

Re page 643, last paragraph:

From experiments we have made we know that the paper of cable the insulation of which is at a temperature of 93½ deg. c. continuously for three or four weeks will become brittle. At 100 deg. c. the paper will reach the same condition in a shorter time. It would seem as though ten years is much too great a life to count upon for, say, 25,000-volt cables, with insulation heated to 100 deg. c., although we know of cases where cables have continued to operate successfully at 2200 volts when the paper was so brittle that the slightest bend in the cable would break it.

Re page 645, paragraph 2:

Except where the cable in the manhole is very heavily lagged it will, in the majority of cases, be the cable in the ducts at ordinary conduit depths—not the cable in the manhole—which is most in danger from overheating. Although the soil at conduit depths may be comparatively cool during the summer months, the air in manholes where no cable is present, or if present, without load, may be quite hot. The cable in the manhole, therefore, will, during this season of the year, be at a disadvantage (insofar as actual temperature is concerned), as compared with the cable in the ducts. The ducts and surrounding earth, however—cooler though they would be in summer than the air in the manholes, permit of the dissipation of heat from the cable much less rapidly than occurs in the manholes.

In the winter the reverse conditions obtain. The air in the manholes, without cables present, or if present without current, is usually much cooler than the soil at conduit depths. The cable in the ducts, therefore, is at all seasons of the year under the greater liability to damage through overheating, except, possibly, in the summer in manholes where the cables, instead of being left bare, are so heavily covered with asbestos, or rope and mortar, or other protective covering, as to approximate the relatively poor cooling conditions existing in the ducts.

Although the maximum temperature in the manhole (with unloaded cable) probably varies pretty closely with the diurnal temperature wave as represented by the temperature of the free air at the street surface, the soil temperatures at conduit depths follow more closely the integrated effects of the sunshine falling on the street's surface at that point.

Without actual measurement of the temperature, which would have existed in the duct had the cables therein given off no heat at all, it is believed that the best predictions as to its probable value are based on the general relationship between the mean air temperatures taken over some considerable period, such as a week or a month, and the corresponding soil temperatures, as found, for instance, by Prof. H. L. Callendar, McGill University, Montreal.

Callendar's data show maximum temperatures at 40 inches below the surface of—

41 deg. for December, 1894
42 deg. for December, 1895
38 deg. for December, 1896

These values are about 20 deg. f. above the mean monthly air temperature for the same periods. Assuming the same conditions prevailed at Boston in December, 1912, the soil at conduit depths would have had, at sometime during the month, a temperature as high as 58 deg. f. This is 8 deg. f. higher than assumed by your Report, but, possibly not as high as actually existed, since other data at hand indicate that for different soils and different kinds of paving and weather from what are represented in the Montreal. tests, the resulting soil temperatures might be considerably higher. In the absence of specific measurements of soil temperatures at conduit depths in various kinds of soil with different kinds of paving material, exposed to different amounts of sunshine and shade, rain, snow and sleet, it is probably not too conservative to assume that for the larger cities, such as Boston, New York, Philadelphia, Chicago, Pittsburgh and Buffalo, there may be days in December, even in years of normal seasonal weather when the soil temperature at conduit depths is as high as 60 or 65 deg. f. In the years of abnormal heat during the fall months it may be still higher.

If the user of cable contemplates taking advantage of the cooler parts of the year to operate his cables at heavier load, it

would seem not unwise to doubly guard his cables in hot weather. In other words, where he has spare cables, particularly of high voltage, he should use several at light load rather than one at heavy load. It seems highly probable from our knowledge of the displacement of the phase of the diurnal wave of temperature and the reduction in amplitude as we go below the surface of the soil, that the time to look for the overheating of cables under constant load, insofar as it may occur in the ducts, is not during the hottest part of the hottest day, nor even within the limits of that day, but during the period which may succeed the hottest day or days by a week, two weeks, or possibly longer, where the conduit is at considerable depth.

Re page 646, last paragraph:

A load of 300 amperes on 4/0 triplex cable, or a current density of 1.4 amperes per 1000 cm. as suggested, would appear to give, on the average, unduly high temperatures in the winter on very low-voltage cables and temperatures eventually destructive, in many cases, on high-voltage cables.

From experiments our engineers have made, I believe average conditions are represented with a high degree of probability by the following data in duct systems of six or eight ducts (based on Niagara Falls tests, see data S. U. C. Co., Handbook XVII, pages 192 to 194, under which specific conditions the data are quite exact).

Cable assumed to be, 3-conductor, 4/0, carrying 300 amperes.

	One Cable In Duct Sustem. Deg. F.	Deg. C.	Four Cables In Duct System Deg. F.	Deg. C.
(a) Rise of temperature of duct system above the earth.....	23	13	75	42
(b) Rise of temperature of insulation near conductor above the duct system	116	64	116	64
Total rise in temperature..	139	77	191	106
If the temperature of the earth at similar depth below surface at point removed from the influence of cables be taken at an average winter value of, say, 50 deg. f..........	50	10	50	10
Final temperatures attained in the duct (not the manhole) will be, from the current flowing alone, 24 hours per day)	189	87	241	116

But these temperatures are for cables heated only by the current in the conductors. For high-voltage cable the temperatures attained will be much greater—so much greater as to reach, in all probability, the critical point at which the rate of dissipation of heat is less than its generation—the temperature rising higher and higher until breakdown occurs. Even if we assume such an insignificant additional rise of temperature as 23 deg. f., or 13 deg. c., as being due to the high voltage impressed on the cable we get—

	One Cable In D.uct System.		Four Cables In Duct System	
Final temperatures attained for	Deg. F	Deg. C.	Deg. F.	Deg. C.
24-hour load, high-tension.	212	100	264	129

With one cable in the system the temperatures are such that the paper becomes brittle in two or three weeks. With four cables it becomes brittle in a shorter time.

If the load is on the cables only six hours per day the rise in temperature of the duct system (a) might reasonably be expected to be less than the above by 15 deg. f., or 8 deg. c. for one cable, and 49 deg. f., or 27 deg. c. for four cables, thus giving—

	One Cable In Ducf System		Four Cables In Duct System	
Final temperature attained for	Deg. F.	Deg. C.	Deg. F.	Deg. C.
6-hour load, high-tension..	197	92	215	102

The temperatures are still so high that the paper would become brittle in a few weeks, even allowing for the fact that the cable is heated to that temperature but six hours per day.

The above values may, in certain not unlikely cases, be somewhat reduced; in other cases, no more unlikely, they will be so much increased.

A test was made to give more light on the combined effect of dielectric loss and current loss as applied to such cables.

A 3-conductor, 4/0 B. & S., 7/32-inch by 7/32 inch paper, lead-covered cable was lagged slightly with felt, in order to simulate the conditions of an unlagged cable in a duct, or a wrapped cable in a manhole, and with 225 amperes flowing at a very low voltage through each of the three conductors (which were connected in series) was brought to a steady temperature for the copper conductors of 204 deg. f. 13,700 volts was then applied between the three conductors and the sheath, while the current was kept at 225 amperes or less, with the result that

within 10 hours the cable conductors reached a temperature of 580 deg. f., and the cable then broke down. This voltage between the conductors and the sheath would, with a uniform dielectric represent a dielectric loss about equal to that of a 3-conductor cable with relatively thick insulation operated at about 18,000 volts, 3-phase.

Re page 646, paragraph 2:

The maximum temperature of 150 deg. f. is not acceptable to English manufacturers; yet the Standard Underground Cable Co. has, for years, offered guarantees on cables when operated at no greater temperatures than this (Handbook XVII, 1906, page 194).

Re page 648, paragraph 2:

The cooling conditions under which the cable operates are largely determinative of what will happen with high-voltage cables. If the cable is laid in a duct system surrounded by ashes, or by very dry sand, or by any other material which is a particularly good heat insulator, it will require very little energy appearing in the form of dielectric loss to carry it to ultimate destruction. High initial temperature of surroundings is the practical equivalent of poor cooling conditions even though the material directly around the cable is of good thermal conductivity. I know of instances where high-voltage cables operating at apparently conservative ratings have burnt up in ducts laid through earth largely composed of ashes, one cable after another failing at the same point during hot summer weather. Cables used within hot stations in ducts too well insulated thermally, as well as aerial cables exposed to the hot sun, have burnt up under what might be assumed to be comparatively low current loads; and similar consequences have resulted with cables in ducts lying too close to reheating furnaces, such as are used in rolling mills. Even with an absolutely uniform dielectric, a spot would develop in practice which would be hotter than any other part of the cable, were the heating due solely to current flowing in the conductors, and not, in any measure, to the leakage of current through the dielectric. This is due to the variation in the temperature of the duct structure or to variation in its capacity for dissipating the heat developed in the cables, or to both causes. If voltage of sufficient amount is then applied to

such a cable, it will be this hot spot which will go to destruction, although electrically it was as strong as any other part of the cable when the insulation was at a uniform temperature throughout its length.

The results of two of a number of experiments, made on the heating of cables, may be mentioned to show that it is not necessarily at the weakest spot in the cable, but rather at the spot where it becomes most difficult for the cable to dissipate its heat that overheating and ultimate destruction take place. The first experiment was on a piece of cable 80 ft. long, which, on account of the slight inequalities of thickness in the lagging, or slight variation of temperature in the surrounding air, developed hot spots at 68 ft. and 51 ft. When the temperature of the sheathing at the 51-ft. point was 222 deg. f. and that at the 68-ft. mark was 218 deg. f., the lagging at those points was removed for about two feet on each side. The temperature of the lead sheathing began to fall rapidly, and, within four hours, the 68-ft. point was at a temperature of 140 deg. f. The 51-ft. point dropped in temperature to 150 deg. f. within two hours, and then started upward again and two hours later was at a temperature of 245 deg. f., and was rapidly going to destruction. The improvement in cooling conditions had not taken place quite soon enough to save the 51-ft. point. Had the lagging been removed but a few minutes earlier the cable would probably have been saved. Other tests were made in which hot spots were allowed to develop only far enough to show conclusively that the cable was going to destruction by cumulative heating at which time the current and voltage were cut off and the hot spots allowed to cool down to room temperatures. Then, after removal of the lagging at the hot spots, the current and the voltage were re-applied, whereupon it developed that the former hot spots now remained cool.

The second experiment was made to determine whether a hot spot could be developed at any point on the cable at will. After the cable had been brought to a steady temperature with both current and voltages applied, it was found that a hotter spot than the remainder of the cable had developed at the 26-ft. thermometer and that the 45-ft. thermometer was among the coolest. Extra lagging was added at the 45-ft. point, and, after continuing the test for about 48 hours, it was found that, while the original hot spot at 26 ft. had developed not at all, the cool spot at 45 ft.

had developed into a hot spot and was well on the way to destruction.

Re page 649, paragraph 1:

When a hot spot on high-voltage cable becomes well started toward destruction the rate of heating is so fast that a very considerable pressure may be generated, as much as 80 lb. per sq. in. in one experimental case, or sufficient to burst the lead sheathing. The sheathing may burst at a point many feet away from the hot spot which is responsible for the existence of the pressure.

Re page 649, paragraph 2:

It would appear that the liability to breakdown of the insulation is a function of the cooling conditions as well as of the actual temperature of the insulation. In an experimental case the conductors of a lagged cable were brought to a steady temperature of 177 deg. f. by means of a $C^2 R$ loss in the conductors alone equal to 4.1 watts per foot, the sheathing then being at a temperature of 135 deg. f. 13,000 volts were then applied and the cable went to destruction in about 48 hours. A slightly lesser current in the conductors previously applied was shown to be insufficient to cause destruction by cumulative heating at this voltage. The damaged portion of the cable was then cut off and a portion of the remainder, with the lagging removed, was brought to a conductor temperature of 279 deg. f. and lead temperature of 138 deg. f., with 18 watts $C^2 R$ loss. 13,000 volts were then applied, and after a few hours it was found that the temperature was rising so rapidly at one spot that destruction of the cable was probably inevitable, though a matter possibly of some days. A slightly lesser current previously applied was shown to be insufficient to cause the cable to go to destruction by cumulative heating, although, of course, a temperature of 279 deg. f. would have caused destruction of the cable ultimately by slow chemical changes. It is not the slow process we are concerned with here, however, but rather the rapid destruction by rapid increase in temperature after the critical temperature for that particular cooling condition has been reached. It would thus appear that the critical temperature of insulation at which the cable would continue upwards to the point of destruction, is higher in a well-cooled cable than in a poorly cooled cable. In other words, the better the cooling conditions the higher the temperature at which

the insulation may be worked for the same factor of safety against the more or less rapid destruction due to cumulative heating.

Re page 649, last paragraph:

Is the evidence conclusive that the insulation will not ultimately be ruined by running the cable at a temperature near the danger point?

Experiments on lagged cable under laboratory conditions show that where a hot spot is developed and allowed to go to destruction, there may be, and usually are, other points on the cable where the insulation has been heated beyond the safety point —the insulation showing signs of brittleness and even of charring. In other words, the suggested "safety valve" action of the spot which burns out first is inadequate, in short lengths of cable at least, to protect the remainder of the cable. It is doubtful if the recommended course of running cables to their limit of heating may be pursued even with longer lengths than those experimented upon without grave danger to the remainder of the cable. Tests at 13,000 volts and with a $C^2 R$ loss approximating 4.1 watts per ft. on a piece of 3-conductor cable 130 ft. long, lagged to approximate subway conditions, show, in one case, that at the time the hottest spot had gone far enough toward destruction to burst the lead sheathing (although the cable did not break down at this point until the voltage had been raised to 17,000), two other hot spots had developed to a point where the insulation was seriously damaged.

By the use of thermometers applied directly to the lead sheathing, and exploring resistance thermometers which were passed lengthwise through specially made hollow conductors, we know that the temperature of the dielectric at the sheathing and near the conductors was about as follows:

	Temperature of Conductors	Temperature of Sheathing
At 81 ft.—the hottest spot	435 deg. f.	310 deg. f.
At 49 ft.—the next hottest spot	330 "	272 "
At 118 ft.—the next hottest spot	310 "	265 "

The dielectric even at these secondary hot spots had been at a temperature of 200 deg. f., or more, for five hours before the hottest spot caused the bursting of the lead sheath; and at the discontinuance of the test it was found to be quite brittle and, in places, somewhat charred.

If we assume one spot existing originally very much weaker than the rest of the cable and it "lets go," as described, and this acts as a safety valve, will not the removal of that very weak fault leave the cable nearer the general average of strength? If so, the heating of the cable until the second weakest spot lets go must, in reality, be heating it to a point nearer the danger zone, and with each fault developed and removed, the safety valve action is decreased to the vanishing point. As the factory and installation tests operate to remove the weak spots, if any exist, it seems only reasonable to assume that the part of prudence is not to operate the cable near the danger point.

Re page 663, paragraph 1:

Since equity must, in the long run, be the condition of maximum good to buyer and seller alike, anything which makes for the attainment of that end is certainly worth striving for. A slight modification of the wording of this clause will, it is believed, more surely bring about this result.

The manufacturer obviously is at fault only so far as he uses poor materials or poor workmanship in the making and installing of the cable. His responsibility for breakdowns, therefore, should most reasonably be limited to the result—not of the faults or misfortunes of the buyer—but of his own faults. Since the manufacturer has absolutely no control over the cable after it is put into service by the buyer and has no knowledge of, and cannot affect the conditions under which it operates, he is obviously not at fault if the cable breaks down through the deteriorating influence of current overloads or surges, either of excessive values for short durations or of moderate values often repeated—by no means infrequent occurrences, although few operating companies keep continuous records of them.

If the manufacturer is asked to assume the responsibility for such breakdowns the cost of insurance against this risk must be added. The difficulty, or rather impossibility, of accurately determining this cost of insurance will make it necessary for the manufacturer to add a sum sufficient to protect him—not against the few breakdowns he hears of as actual occurrences on a system well equipped with surge protectors and operated with the utmost conservatism as regards the load; not against unfavorable switching conditions, nor even against the

much larger number of breakdowns which have developed on systems representing average conditions; but against the greater number which will, in all probability, develop in the future on the average system after the incentive for conservative use of the cable has been weakened or largely removed by shifting the penalty for the user's possible abuse of the cables, or lack of care in their operation, to the shoulders of the manufacturer.

High-voltage cables, being particularly vulnerable to heavy current overloads, especially in hot weather, will, on the average, develop more breakdowns from abuse or careless handling than low-voltage cables. In the absence of complete records of the load on that particular cable the user may honestly feel that the manufacturer is responsible for something which is the user's fault alone.

Re page 664, paragraph 4:

The testing of cable lengths at 150 deg. f. should be limited to sections taken at random and preferably representing but a small percentage of the total amount of cable, if the cost of the cable is to remain more or less unaffected, as the additional heating devices and the time required for the cable to attain this temperature must largely increase the cost of manufacture and seriously retard the rate of delivery.

Re page 664, paragraph 2:

It is doubtful if the manufacturer can learn whether the lead he gets from the smelters is freshly mined ore or not. If the intention is to have the lead freshly smelted or to obtain assurance that it has not been used for other purposes, a change in wording to this effect would be desirable.

Re page 665, paragraph 2:

It is my belief that tests of five times the working pressure applied for five minutes on samples from 10 to 25 ft. in length are so great as to defeat the ends of the buyer. Four times the working pressure for voltages not above 25,000, and a lesser factor for higher working pressure, are certainly adequate to determine the character of insulation entirely suitable for continuous operation at the working pressure stated. To make the test equal to five times the working voltage where it is equal or less than 25,000 will almost assuredly require the manufac-

turer to increase the thickness of insulation and hence the cost of cable beyond what the working conditions require and for voltages above 25,000 it is quite conceivable that it would impose a condition practically impossible of achievement.

The experiments referred to herein were carried out for me by Mr. R. W. Atkinson, who also made most of the calculations.

Mr. W. H. Cole, Boston (submitted in writing):

The Committee has, as usual, done valuable work, as is indicated by the information brought together in this report. I beg leave to present the following comments:

Specifications for Paper-Insulated Cables

It seems to me that until actual bending tests are made on foreign-made paper-insulated cables in direct comparison with American-made cables, it would be unwise to include any rigid bending tests. Experience in the inspection of paper-insulated cables for the Boston Edison Company during the past two years shows that certain American manufacturers can meet in many samples the most rigid bending test yet proposed, but thus far the uniformity of results obtained does not warrant the hope that every cable tested will meet such a test. There being so much doubt expressed on all sides as to the actual interpretation of allowable damage on account of bending, and the certain knowledge that some damage must occur in any bending of paper cables, it seems unfair, at this time, to assume that American manufacturers, as a class, cannot produce cables to meet the foreign idea of what is proper.

Insulating Material

I would suggest the following as being descriptive (so far as the purchaser ought to describe) of cable oil: "A compound guaranteed to retain its initial qualities during the life of the cable, or not to develop any injurious chemical action within itself or with any other component of a finished cable." Beyond this, I believe the buyer should not specify, particularly if the initial tests on the cable are satisfactory to him. Sticky, adhesive qualities may not necessarily be desirable qualities; therefore, we should be very careful not to specify what may be inconsistent combinations.

Tests

The Committee should report more specifically regarding the effects of frequency in testing cables. So far only general statements have been made covering this point, apparently unsupported by actual data. The reference to peak voltages seems to be new and not in line with general recommendations calling for sine wave forms of testing potentials. This, I believe to be unwise, in view of recent agitation for improved testing apparatus. It is also inconsistent with the recommendations of the Committee on Electrical Apparatus, as given in its Report. In view of the disclosures in the Report, bearing on heating of dielectrics, it seems advisable to raise the insulation resistance requirements or change the temperature co-efficients of the dielectrics in order to reduce the cumulative heating effect due to leakage at high potentials.

Specifications for Rubber-Insulated Cables, etc.

It appears to me that a few changes are desirable, based on two years' experience in purchasing under substantially the specifications outlined.

1 Manufacturers should adhere strictly to a specification requiring a tight fit between the lead sheath and the dielectric. Certain cables are so insulated as to not permit of this construction.

2 Certain revisions should be made in the chemical specifications, such as omission of lamp-black and red-lead, and a limitation should be placed upon the amount of rubber extractive matter.

3 A very important requirement not yet covered, to my knowledge, in any mechanical tests specified for rubber-insulating compounds, is one to cover the allowable mechanical fatigue of such compounds under continued tensile stress due to bends made during and existing after installation.

4 Serious objections are made by manufacturers to the voltage rating of rubber cables, as given in the specifications. For this reason much attention should be given to a standardization of working pressures allowable for such rubber compounds.

MR. ABBOTT: In reply to Mr. Davis' gentle rebuke that the Committee was possibly unaware of the work of Mr. H. W. Fisher, of the National Underground Cable Co., I call attention

to the fact that the Committee, in its report, states its full cognizance of Mr. Fisher's excellent analytical work, though the statement, as it now stands, is a somewhat modified form of the previous one: "It does not appear that a sufficiently complete investigation has ever been made to determine the safe limits of loading under the various conditions to which such cables are subjected." This, we believe, does not detract from the excellent work done by others, but, at the same time, we are of the opinion that a good many important topics bearing on this subject and taken up in this report have never been completely considered or discussed.

We gladly abide by Mr. Davis' criticism of paragraph 8, as the version appearing in the Convention copy of the report is worded so as to be somewhat misleading. It was intended to have this paragraph merely bring home the fact that the destructive effect of excessive heating is proportional largely to the length of time that heat is endured, and, as the peak load on lines on most systems is of short duration only, this fact enters materially into the determination of the length of life of cable. The paragraph has since been rewritten to more clearly bring out this point.

Following his criticism pertaining to load on lines, I wish to emphasize what must be borne in mind, that the present rating of cables in most central-station systems is based on a daily load curve, the average of which is very much below the peak, and that full loads are carried but a comparatively short time each day. An examination of an annual load curve of any operating company will make this point clear.

Mr. Davis' table of temperatures, I take to be ultimate temperatures, scarcely attained with ordinary or average load conditions. The maximum load of average systems, and, consequently, the maximum load on lines, as a general proposition lasts scarcely an hour each day, and this length of time is not likely to permit the cables to even approach ultimate temperatures.

Concerning his criticism in regard to test voltage, this is conforming to specifications used by foreign companies.

The remaining part of Mr. Davis' criticism I believe to be a valuable contribution to the subject under discussion, and I

trust that the next Committee will give it the consideration it deserves.

To me, Mr. Cole's remarks on the bending tests are rather severe. This particular test was prescribed in conformity with the cable specification prepared by Messrs. Merz and McClellan, but deprived of much of its original severity. The English specifications call for bending the cable six times in successively opposite directions around a cylinder 12 times the diameter of the cable over the lead sheath. These specifications last year called for performing the bending operation but four times. This year a further decrease in the severity of the test was made by increasing the diameter of the drum over which the cable was to be bent from 12 times to 15 times the cable diameter. As the crucial test to determine the effect of these bending operations lies in the application of the voltage test, little concern need be felt relative to actual interpretation of allowable damage on account of bending.

The proposed form of definition for insulation given by Mr. Cole is, I believe, not sufficiently far-reaching. A good many breakdowns have been attributed to the extreme fluidity of the compound, causing the latter in cables resting in positions deviating from the horizontal to seek the lowest levels at anything higher than most moderate temperatures. These specifications were intended to secure impregnating compounds of sufficient viscosity not to suffer such displacement, a result which could scarcely be obtained under Mr. Cole's specifications. The expulsion of all air and moisture is likewise an important item as the pressure of these might not, in all cases, be revealed by a breakdown test of short duration, especially after installation.

As Mr. Cole states, there is a total absence of information relative to the effect of frequency in testing cables and this is an extremely broad and perhaps an interesting subject, which we are glad to leave for the next Committee to consider.

Concerning the spark method of determining peak values of test voltage, it was the Committee's opinion that this did not necessarily mitigate against the highly desirable tendency to use machines of good sine characteristics, but, at the same time, it is a safeguard and assures that in the tests a peak value of voltage will be used corresponding at least to the peak value of the equally effective value of a sine wave. One of two specifications

was necessary; viz., to stipulate the spark method or to spe machines of perfect sine wave characteristics. The Comm chose the former as being more easily complied with.

In Mr. Cole's recommendation concerning increased ins tion resistance, or what he terms changed temperature coeffi of the dielectric, which, I take to mean less diminished insula resistance at higher temperature, lies an interesting and extre important problem for our manufacturers. Mr. Cole's comm concerning specifications for rubber-covered cable present se new thoughts, and the Committee begs to commend them to most serious consideration of its successor.

THE CHAIRMAN: The next number on our program afternoon is a paper by Mr. H. H. Rudd, of Pittsburgh, ent "Transformers for Power Transmission."

TRANSFORMERS FOR POWER TRANSMISSION

Much has been written regarding the part that the transformer has played in the development of the electrical industry, by making it possible to utilize the more distant sources of power, whether of water, coal or culm at the mouth of a mine. For the transformer manufacturer, however, one of the most interesting and important developments at the present time is not the equipment for distant sources of power, but that required by the concentration and centralization of the sources of power and their local distribution.

In Mr. Insull's speech made before the Franklin Institute, is given briefly an idea of what are to be the economies of the future. The transformer has a very important part to play in the work outlined. It is the piece of apparatus that makes it possible to tie together town and country, railway and industrial loads, for the betterment of plant efficiency by an improved diversity factor.

The many small generating stations over the country must necessarily in time be replaced by the much more economically maintained sub-stations of large central stations. Such sub-stations and their loads are now being made the subject of careful study by central stations. It is interesting to note the choice made by a number of power transmission companies of voltage for distribution where there are a number of small communities to be supplied. The voltage must be high enough for economical transmission and yet not so high that the cost of substation equipment, consisting of transformers, switching and protective apparatus, is too great to make possible, from the small community and farm load, a fair return on the capital invested. The higher the voltage chosen, the greater must be the size of the individual load to justify the installation.

In considering the small-capacity high-voltage transformer it is well to have a fair idea of the effect of size on cost. In this type the cost of the terminals and bushings is practically independent of size. The cost of labor increases but little with the kilovolt amperes, so that for very small transformers little saving can be made by going to an extremely small size. A minimum in size is thus reached which we will say is the smallest size that

is commercially practical, and that size is such that a further reduction in capacity of 50 per cent reduces the cost by not more than 10 per cent. The smallest commercial sizes under such a definition will be approximately:

For 11,000 volts	....	2½ kilovolt amperes	
" 22,000 "	....	10	" "
" 33,000 "	....	15	" "
" 44,000 "	....	15	" "
" 66,000 "	....	25	" "

The figures that are interesting to the central station include not only the costs of the transformers but of the switching and protective equipment, including the necessary substation costs.

The development at moderate cost of an outdoor transformer and its switching and protective equipment and of an inexpensive

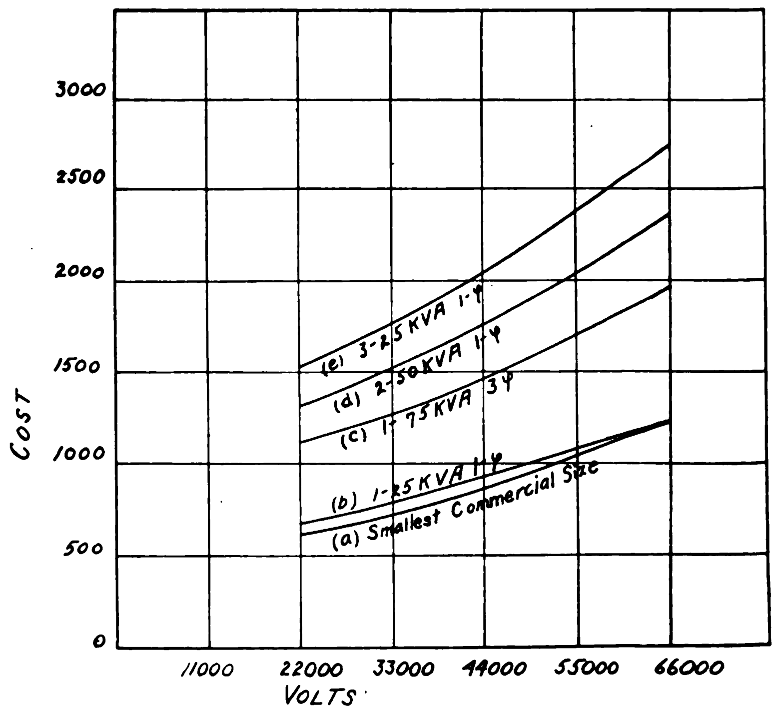


FIG. 1. RELATION BETWEEN COST OF INSTALLATION AND TRANSMISSION VOLTAGE

FIG. 2. 300-KV-A. OUTDOOR SUBSTATION, COMPLETE, 22,000 VOLTS

outdoor structure have made the economical voltage for transmission in the neighborhood of 22,000 or 33,000 volts where there is an extensive small community and farm load. These voltages are high enough to carry a considerable distance with small loss

FIG. 3. CORE AND COILS, SMALL-CAPACITY TRANSFORMER, 22,000 VOLTS

and the cost of the equipment is not excessive. Fig. 1 shows a comparison of costs for different installations: (a) single-phase installation using the smallest size of transformer that is com-

mercially practical; (b) the same, except that the size is 25 kilovolt-amperes for all voltages; (c), (d) and (e) comparisons of 3-phase installations, (c) consisting of one 3-phase trans-

FIG. 4. KV-A. O.I.S.C. TRANSFORMER, 22,000 VOLTS, OUTDOOR SERVICE

former; (d) of two single-phase, to give approximately the same 3-phase capacity when connected in open delta and (e) of

three single-phase transformers of one-third the capacity. These are on the basis of 60-cycle and include costs of transformers, switching and protective equipment, structure and estimated cost of installation.

A great deal has been written on the subject of 3-phase *versus* single-phase transformers. On transformers of small capacity and high voltage, the constant or nearly constant element of cost which enters in is a very large proportion of the total, and a 3-phase transformer may show up considerably to the good on price and performance when compared with the cost of three single-phase transformers of one-third the capacity. The use of two single-phase transformers of larger size connected in open delta seems to answer the arguments also. The particular advantage of the single-phase transformer for this service is that the single-phase has lower first cost and the first step in developing a load can be easily accomplished by a single-phase installation. When the load grows, the next step is the addition of another single-phase unit, the two being connected in open delta, thus better distributing the load over the phase of the system. This arrangement will provide for taking 3-phase power contracts. As the combined load grows, the third transformer may be added, completing the delta.

There has been a very decided and marked growth in business the past year in small-capacity high-voltage transformers; that is, transformers for capacities up to 100 or 150 kilovolt-amperes and voltages above 16,500. A statement that the installations have been as many this past year as in all years previous would not be much of an exaggeration. The growth has been phenomenal, for three reasons. The power and transmission companies have realized the importance of the electrification of the small community and the farm, and manufacturers have put on the market a thoroughly reliable transformer at moderate price. A big factor also has been the development of outdoor switching equipment of low cost to meet the demand.

A requisite for strong and permanent growth is that the additions shall be along broad standard lines. It is desired to emphasize this point, which is in the nature of a plea for standardization along the line of voltages and taps.

In this class of high-voltage distribution a problem that often confronts the transmission company is what voltage shall

be used for the local distribution. A considerable load perhaps is available at 110 volts near the sub-station and the balance of load some distance away. It is apparent at first sight, on account of the greatly decreased cost per kilovolt-ampere that a transformer having a double low-voltage winding will be the right thing, one winding at 110 volts to supply the load near by and the other at 2300 volts to take care of the more distant demand. Assume that a community will require 100 kilovolt-ampere capacity and of this about 75 per cent will be required at 110 volts and the balance at 2300 volts, for a mill located some distance away. It is quite possible to make a transformer of such design, but to provide proper clearance for insulation and the special terminal board may mean a transformer of slightly larger parts, resulting in greater cost and poorer performance. At a future time the demand for the same percentage of 2300 and 110 volt supply may change, and the transformers which have been bought for the local conditions will no longer meet requirements. One installation may require 75 per cent at 110 volts and 25 per cent at 2300 volts, whereas another may require the proportions reversed or altogether different proportions.

If we should represent say a 50 kilovolt-ampere 22,000-volt transformer as having a price of 100 units, the price of a 50 kilovolt-ampere with two low-tension windings would be approximately 10 per cent more than the standard, or 110 units. It is true that this is considerably cheaper than two units, one of 15 kilovolt-amperes and the other of 37½ kilovolt-amperes, each stepping down from line voltage, one for 2300 and the other for 110 volts, low tension. It is also probably less in first cost than the cost of a 50-kilovolt-ampere standard 22,000-volt transformer plus the cost of a 15-kilovolt-ampere standard 2200-volt distributing transformer.

The transmission line often passes farms where there is not sufficient load to make it worth while to tap the main line but enough to be very desirable if it could be taken care of at a lower voltage. The most economical way is to step down at the center of distribution and run either way on the transmission pole line at a lower voltage. Where a town is a center of distribution, as is often the case, it may apparently be advisable to use a double low-voltage, one for 2300-volt distribution and the other for the voltage used on the farm line.

Looked at from the point of performance and real flexibility, however, the advantage seems to lie with the transformer having a single low-tension winding. These arguments will, of course, not hold for every case, but they do hold for the transformers under consideration, that is, of small capacity and high voltage.

The natural flexibility of the transformer is responsible also for the number of series-multiple requirements of high-tension and low-tension windings, some of which are easy of provision and do not complicate the design, whereas others are very difficult to meet.

Provision can be made on the high-tension side for series parallel arrangement, but this is a feature which adds to the cost of the transformer. If a majority of central stations have need of such a combination in their distribution systems, then the standard transformer should be built to meet such requirements. There seems to be a well-recognized demand that where a voltage of 220 is required on the low-tension side, provision for 110 volts by multiple connection should be provided. This requirement is reasonable and can be easily obtained. For 440 volts, low tension, a multiple arrangement of 220 can readily be given In view of the number of uses for 110, 220 and 440 volts, a transformer having the low-tension designed for obtaining all three voltages might be a logical standard.

Requirements for a low-tension having ten low-tension coils in parallel for 220 and placed in series for 2200 are not easy to obtain and would result in greater cost and complications. Is the need for such a combination the need of the majority of users? A requirement of 2300 and 575 volts is not so bad, as it is a four-part symmetrical arrangement; 2300 and 460 volts, a five-part arrangement, is not symmetrical and requires more liberal construction. With the necessity for series parallel arrangement, to provide taps is extremely difficult if not altogether out of the question.

A point on which there seems to be the most diversified usage is the one of taps. On this question there is a great difference of opinion. Some power companies are using transformers having four 2½ per cent taps; others 3, 6 and 9 per cent taps; others five 2 per cent taps; others 4½, 9 and 13½ per cent taps. These are the more common ones. Some require eight taps totalling 18 per cent; others 10 taps for 10 per cent

The number of special requirements is almost legion. The argument is not made that any one of the aforementioned voltage tap arrangements is of necessity the right way, but there is no denying the fact that it is surely wrong to have so many different arrangements.

One of the greatest drawbacks to the good of the industry to-day is the needless special requirements of individual companies. One company desires one arrangement; another wants something different—not very different, but yet enough so to make it impossible for the manufacturer to use stock designs and stock parts.

The transformer is a very flexible piece of apparatus and its very flexibility makes it a plaything in the hands of many. The manufacturer in order to make the apparatus as nearly perfect as possible would cut out all taps and all features which tend to make complications. The power user would have a variety of taps so that the transformer could be used for any and all conditions.

Is there not a middle course that can be agreed upon between user and maker which would result in a piece of apparatus flexible enough for all practical purposes, yet not too complex for the manufacturer to make well? It is believed that for 90 per cent of the power transmission companies transformers having certain high-tension voltage and taps and certain low-tension voltage and taps could be agreed upon as standard. Such a standardization would work for the good of the manufacturer in his not having to provide something just a little different for every case. It would work to the advantage of the power companies by enabling them to obtain quicker deliveries from the manufacturers and eventually lower prices.

It is difficult for anyone who has not been concerned with the manufacturing process to understand the tremendous total waste of effort, the loss in costs of designs, the demands on manufacturing information and the chances for errors in production that follow even slight differences in design.

To make the first cost of the transformer low and render practical the distribution on a small scale of high voltages it is necessary to eliminate the space required for a multiplicity of taps and complicated terminals boards.

The transformer has been a most flexible piece of apparatus in that it can very readily be built to meet local conditions. Local

conditions there are and always will be, but these can for the most part be met by standard apparatus. Transformers having these special features cannot command as great a secondhand or salvage value when the need for them has passed. The station loaded up with special apparatus could not be appraised at as high a figure as if the equipment were standard. A purchaser in calling for certain voltage requirements limits his transformers to his use only. Manufacturers cannot afford to carry stocks or stock of parts for special apparatus when the market is limited to the purchases of one company. However, the voltage classes which are standard are well recognized and generally adhered to. The trouble lies not there but in the requirements for taps above and below the standard, series, multiple arrangements, etc.

The question of taps must be looked at from two points:

(1) The total variation in voltage obtainable.

(2) The number of taps into which total variation is to be divided or the percentage variation per step.

In any general distribution scheme what is the allowable drop between source of power and load within which satisfactory service can be maintained? Is it 5, 10, 15 per cent or some intermediate percentage? Does 95 per cent of the load lie within the district which can be fed with a drop of not over 10 per cent? If so is it advisable that all of the transformers be provided with features that are needed for only 5 per cent of the cases? How closely is the voltage to be maintained constant at any given point? If it were slightly above or below that point, how would the service differ?

Do not the variations in service throughout the day extend over a much greater range than 1 or 2 per cent, which are the variations in tap voltages often asked for? It is, of course, not feasible to make changes in the taps hourly to follow the voltage fluctuations. Where very close regulation must be obtained, the solution is the use of a potential regulator.

These questions have been raised to ascertain if there is not a total variation in tap voltage which will fit most conditions and percentage variations which will meet most conditions. With these agreed upon, they will become standards, and any conditions which cannot be met by them will of necessity be regarded as special and to be met by special apparatus.

The transformers of to-day have voltage taps and features widely varied. The transformers of the future should be laid

out along standard lines. With an adopted standard manufacturers can work towards bringing the apparatus to a high state of perfection; the performance will be improved, the cost reduced. It will work to the advantage of the purchaser; it will aid the manufacturer by the elimination of much needless work in designing.

Any power customer having need for transformers other than these suggested standards will have need, therefore, for special apparatus which must be built to meet his requirements. Features differing from the accepted standard will be recognized as such—the performance poorer, the cost greater and the delivery longer than for a standard make. The standard lines must be made with respect to the greatest good for the greatest number.

The question of standards is not a theoretical but a practical and operating one, and must be decided by the operating men. To the National Electric Light Association as representing the operating men this question is put. The manufacturers will gladly welcome anything that can be done and mean to co-operate in every way.

THE CHAIRMAN: If there is to be no discussion let us proceed with the next paper, "Electric-Railway Loads on Central Stations," by Mr. E. P. Dillon, of Pittsburgh.

ELECTRIC-RAILWAY LOADS ON CENTRAL STATIONS

The problem of combining electric-railway loads and central-station loads on one system has received increasing attention in recent years, and in some of the cities of this country great strides have been made toward effecting such combinations successfully.

The problem is naturally one of economics, and it will doubtless be found that each plant requires a solution of its own special conditions, so that no broad rules can be advanced to cover all cases. However, the writer is of the opinion that central-station operators have not given the subject the careful study its importance warrants. It is hoped that this paper, by calling attention to a few well-known cases where central stations are carrying railway loads, and by emphasizing some features that make such loads desirable business for central stations, a few of our companies may be induced to look about them and secure profitable business previously passed by, under the assumption that it was not desirable.

Practically every large central-station company is now equipped with a well-organized commercial department, actively engaged in going over the district with a fine-toothed comb to get additional customers for either power or light; and, in a very large majority of our cities, a customer having a connected load of one or more horse power receives careful attention and his business is actively solicited, while the local railway is overlooked. Yet here is a customer offering a load of several hundred or possibly several thousand horse power at a fair load-factor and at what is now increasingly appreciated—an excellent power-factor.

The Commonwealth Edison Co., of Chicago, is to-day carrying a larger railway load than any other central station in the States. Here the well-defined policy of combining all loads under one centralized organization has been so successfully demonstrated in practical operation as to need but passing comment. Advantage has been taken of the diversity factor between the regular power and lighting load and the railway load, with the result that the investment in generating stations has been

reduced materially over what would have been expended if these loads had been carried separately. No doubt the load taken by the Commonwealth Company with such successful results in this respect has proven a favorable precedent in prompting other important central-station companies to obtain contracts for large blocks of power from the railway companies in their respective cities.

The Detroit Edison Co. also sells a large amount of power to the Detroit United Railways Co. In New York City the Third Avenue Railway Co. a short time ago contracted with the Edison Company for the purchase of all power required, the central-station company in turn taking over the operation of the main generating station of the Third Avenue Railway Co. This power station is now operated in connection with other generating stations of the Edison Company, the former running a part or all the time, as best economy and load conditions require. The Railway Company has an arrangement by which it secures space for substation apparatus in such substations of the Edison Company as are located in territory not now served by the Railway Company's substations. This naturally results in a material saving in substation investment, as it eliminates, to a great extent, the duplication of high-tension lines and substations.

Philadelphia represents another instance of the central-station company carrying a large block of the city railway load. The Philadelphia Electric Co. is now carrying a considerable load of the Philadelphia Rapid Transit Co., and will add more from time to time as sub-stations now under construction are completed. In this case the Electric Company will shortly be furnishing current for both 25-cycle and 60-cycle sub-stations. Twenty-five-cycle current for the Railway Company's rotary converter substations is now being supplied through frequency changers from the 60-cycle generating station, but will probably be furnished later directly from a 25-cycle generating equipment.

The contract between the Cleveland Electric Illuminating Co. and the Cleveland Railways Co. represents a very interesting phase of this subject. The Railway Co. has heretofore been strictly a direct-current system. Several direct-current generating stations were operated and power carried direct to the trolleys through very heavy feeders. The road naturally outgrew this system of power supply. Complete plans for a generating

station with requisite sub-stations were drawn up and accurate estimates compiled.

The Cleveland Electric Illuminating Co., being awake to its opportunities, submitted a proposition to sell power to the Railways Co. in lieu of the construction of the power house. This naturally raised a question on the part of the Railway Company as to which would be cheaper—to buy power from the Illuminating Company or to build its own power house and generate power.

This problem was very carefully studied for several weeks by a Board of Engineers representing the two companies interested and the City of Cleveland, the latter having supervision of all expenditures for betterments made by the Railways Company. The findings of the Board were in favor of purchased power and a contract was entered into for a block of 15,000 kilowatts. The details and terms of this contract have been published in the technical press, and are too voluminous to give in a paper of this kind.

The sub-stations are owned and operated by the Railways Company, and with a view to securing maximum efficiency and maintaining the integrated power-factor at or near unity, 60-cycle rotary converters were adopted in preference to motor-generator sets, the supply system of the Illuminating Company being 60 cycle. In this contract, the feature of the customer earning a premium for high-power factors and vice-versa is rather unusual. In operation, it results in mutual benefit and satisfaction to both the customer and the central station.

Many other cities have companies that have joined together wholly or in part to their mutual satisfaction and profit, but no attempt can be made to list all such cases in this paper.

The rapid growth of systems, bringing the control of both classes of utilities under one head, renders the problem simpler in some cases than if it were merely a question of selling power to a railway company. Another factor that should tend to increase the railway loads carried by central stations is the plan now being developed in many sections to serve an area of a large radius from one well-equipped central station. Such stations are planned to replace the smaller lighting plants and they should likewise be able to displace the smaller railway generating stations.

Let us now consider in detail some of the factors that make it possible for a central station to take over a rotary load partially or completely. Take the case of a railway operating from direct-current generating stations. There are several such roads at the present time throughout the country, and even some suburban roads are so operated. It is only a question of time when the service will grow to a point where the direct-current system is not adequate and the road must make some change to get enough power. For such a road to install a generating station using alternating-current apparatus and transmitting to substations generally means a new station throughout with a rather heavy investment, since the present equipment probably is not modern enough to go with new up-to-date apparatus.

The substation problem is practically the same whether power is purchased or generated. It thus becomes a question of the central station making a rate more attractive than the cost of generating the power with all its attendant expenses. Such problems warrant close study, and care must be taken to include in the result all the items that properly belong to each phase of the problem. However, compared with an efficient, well-organized central station it hardly seems reasonable to suppose that a railway company could be able to build a power house adequate for its needs and generate power cheaper than the central station could furnish it, even at rates to ensure a fair profit.

The writer had an opportunity recently to study such a case. An interurban road had reached the point where it required more power. True, the available records of station output were not very accurate or much in detail. This fact will be met with more frequently than one would at first expect in the case of the smaller roads. On the results arrived at from a preliminary study, there was not much of an advantage either way. This was largely due to inability to accurately determine demand, load-factor and total output. However, the results were sufficiently favorable to purchased power to warrant the central station company in installing the necessary meters in the power house of the railway company and keeping accurate records to determine the real requirements of the road. The final outcome was a contract to sell to the road all its power requirements, and after several months' operation under the contract, the railway company expresses itself very positively as entirely satisfied with the bargain.

In some cases a railway company may be forced to make extensions to its power system, but a more urgent necessity may be found for the use of available funds in betterments of road-bed, equipment, etc. Here is where the central station can step in and take over perhaps a part of the power load with very little increase in its own capacity and yet save money for the railway company. The result is that a profitable customer is secured.

Another rather unusual case is as follows: A large system in one of our cities had been obtaining power from other railways in certain sections of the city where it had no substations or power lines, and it in turn supplied power to these same roads in localities where it had power houses and substations. Following a segregation of the railway companies of the city this company found itself with lines operating in sections of the city where it had no power and could not put power itself without an expensive installation of high-tension feeders and substations. The central station, on the other hand, covering the entire city could easily sell power to the railway through its substations, thereby relieving the railway company of a heavy expenditure and avoiding a duplication of investment.

Diversity factor is another important point to consider in combining loads. Mr. Insull, in his excellent paper "The Relation of Central Station Generation to Railway Electrification," presented before the A. I. E. E., brings this point out very strongly. In this paper he shows the tremendous saving in investment that would result were all the loads in such centers as New York or Chicago supplied from one system and advantage taken of the diversity factor.

Closely allied to diversity factor is the problem of reserve capacity. Assume the railway company to have its separate generating station with a peak load of 5000 kw. and an average load-factor between 40 and 50 per cent. It would then be necessary to install at least three 2500-kw. units with no allowance for growth, thus holding one-third of the station capacity as reserve. On the other hand, if this load were taken by a central station having a peak load of 15,000 kw. and a load-factor of 40 per cent, such a station would probably have three 7500-kw. units, keeping the largest unit at all times as a reserve. To add the railway load to the existing central-station load would require prob-

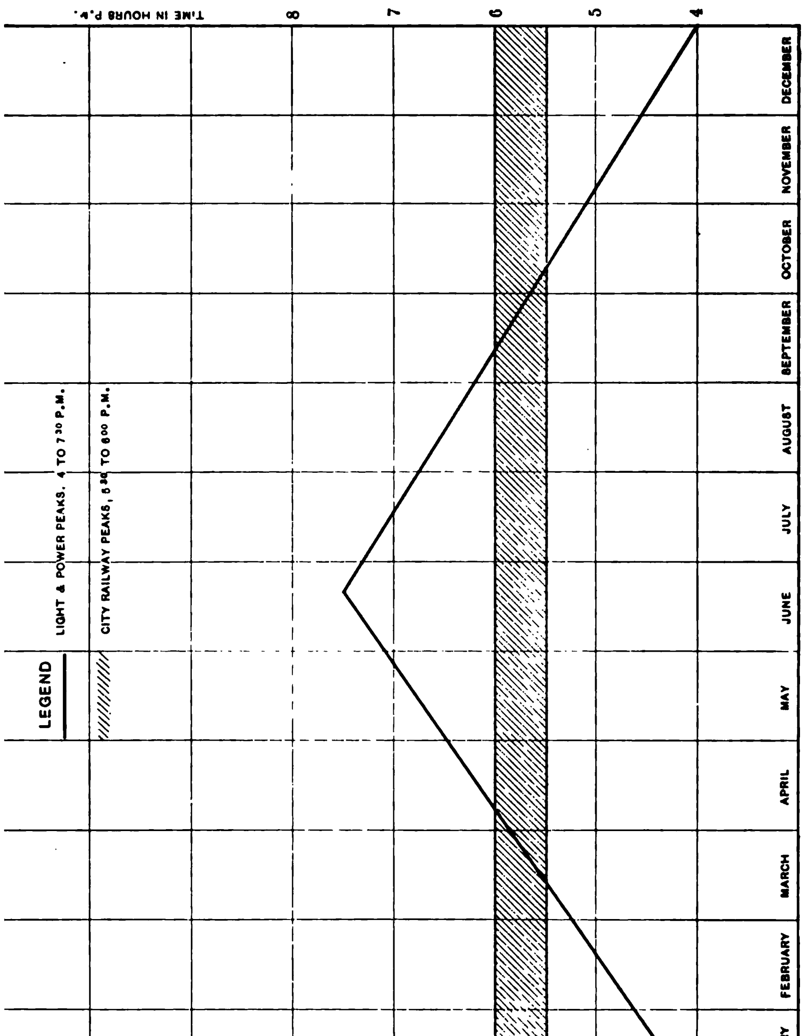

LEGEND
LIGHT & POWER PEAKS. 4 TO 7 30 P.M.
CITY RAILWAY PEAKS, 5 30 TO 6 00 P.M.
TIME IN HOURS P.M.
8
7
6
5
4
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

FIG. I

ably an additional 7500-kw. unit, making a total capacity of 30,000 kw. and a peak load of 20,000 kw. Thus only 25 per cent of

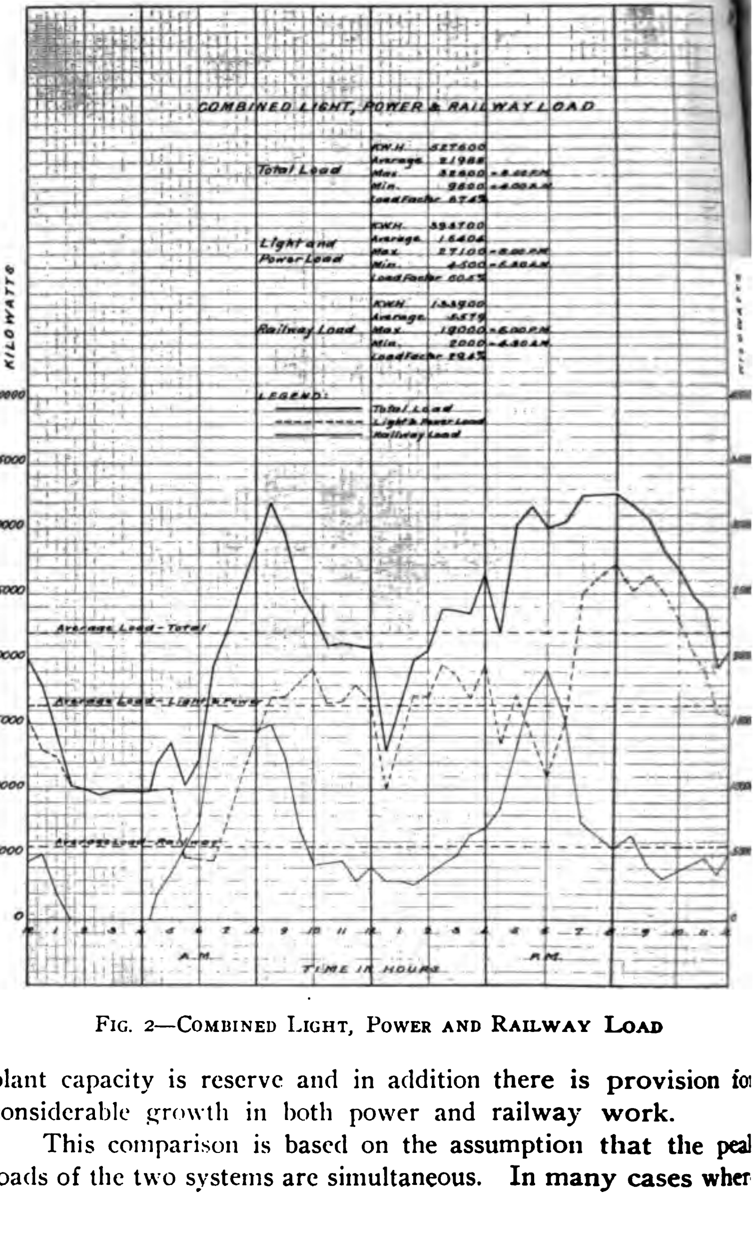


FIG. 2—COMBINED LIGHT, POWER AND RAILWAY LOAD

plant capacity is reserve and in addition there is provision for considerable growth in both power and railway work.

This comparison is based on the assumption that the peak loads of the two systems are simultaneous. In many cases wher

e obtainable portion of the railway load is a smaller proportion the central-station load, it will be found possible to carry such ad with the usual reserve capacity, thereby requiring no addinal investment for generating equipment.

The claim has been made that railway loads are undesirable r central stations, since the peaks of the two systems may be incident, and the central station company should have capacity er and above its requirements sufficient to carry the railway ad. This is true to a certain extent only. Referring to Fig. 1, is well known that the railway peak is fixed at some time tween 5:00 p. m. and 6:00 p. m. throughout the year, while the ghting peak swings from probably 4:00 p. m. to 7:30 p. m., ith the seasons. As illustrated in the curve, it will be seen that e two peaks are coincident twice during the year. Depending on the nature of the central station load, whether largely lightg or largely power, these lines cross or may keep together for considerable time. Even in the worst condition, where the two aks fall together, there will be found a considerable diversity ctor. In addition it will be found that the load factor is iproved by the railway load, and it is an open secret that the presentatives of central station companies are very desirous picking up loads where it can be shown that the load factor in e system will be improved.

Fig. 2 shows a typical day-load curve of a city railway, a cenal-station light and power load, and the combined load of the ilway with the light and power. This total curve shows that the ilway load has not materially affected the characteristics of the ght and power load. The peaks happen to be almost coincident, it the load factor is increased 6.9 per cent, or from 60.5 per cent 67.4 per cent.

Fig. 3 shows a load similar to Fig. 2, but in addition this stem carries a small interurban road. This curve shows a orning peak almost equivalent to the evening peak, and the ad factor is increased from 68.4 per cent for the light and power ad to 71.5 per cent for the entire system. The suburban load such a small portion of the total that its effect is almost egligible.

Figs. 4 and 5 are typical urban railway loads and a suburban ilway load on the scale of the total system, also magnified veral times to get a true idea of the characteristics of the load.

Except on the very large systems, practically all central stations operate at 60 cycles. In the earlier development of railway work a frequency of 25 cycles was generally adopted. This difference in the frequency may be a handicap in certain cases, making it difficult for the central station to take on a railway load. In recent years, however, there has been a marked change

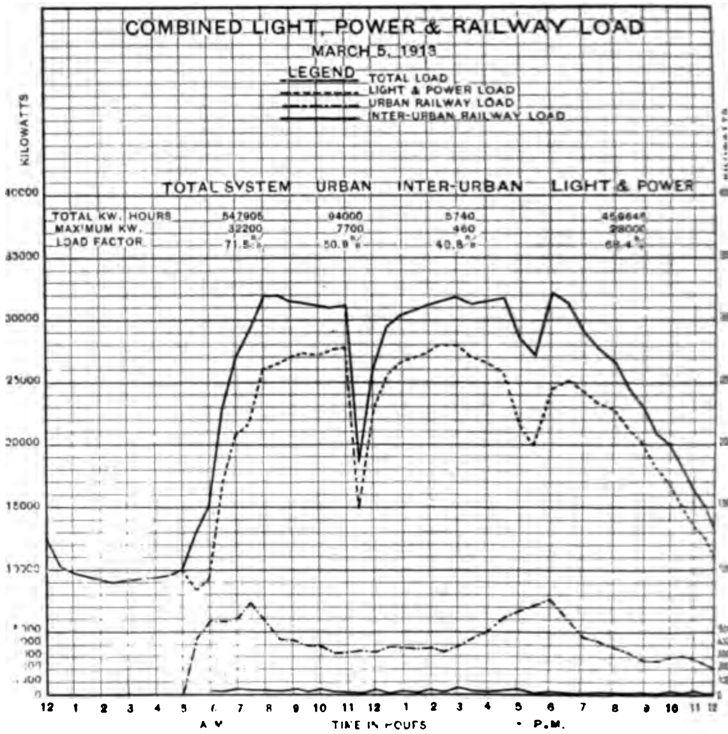


FIG. 3—COMBINED LIGHT, POWER AND RAILWAY LOAD

in railway practise, and we now find a large part of new railway work utilizing 60 cycles. There is a very good reason for this change. At the outset, the 25-cycle rotary converter offered by far the most reliable and satisfactory medium for transforming from alternating-current to direct-current for trolley service. The motor-generator has never been a serious competitor of the rotary converter on 25-cycle systems.

Further, as the railway system was intended to supply only railway load, the lower frequency suited the conditions very well. However, following the move to combine numerous towns under

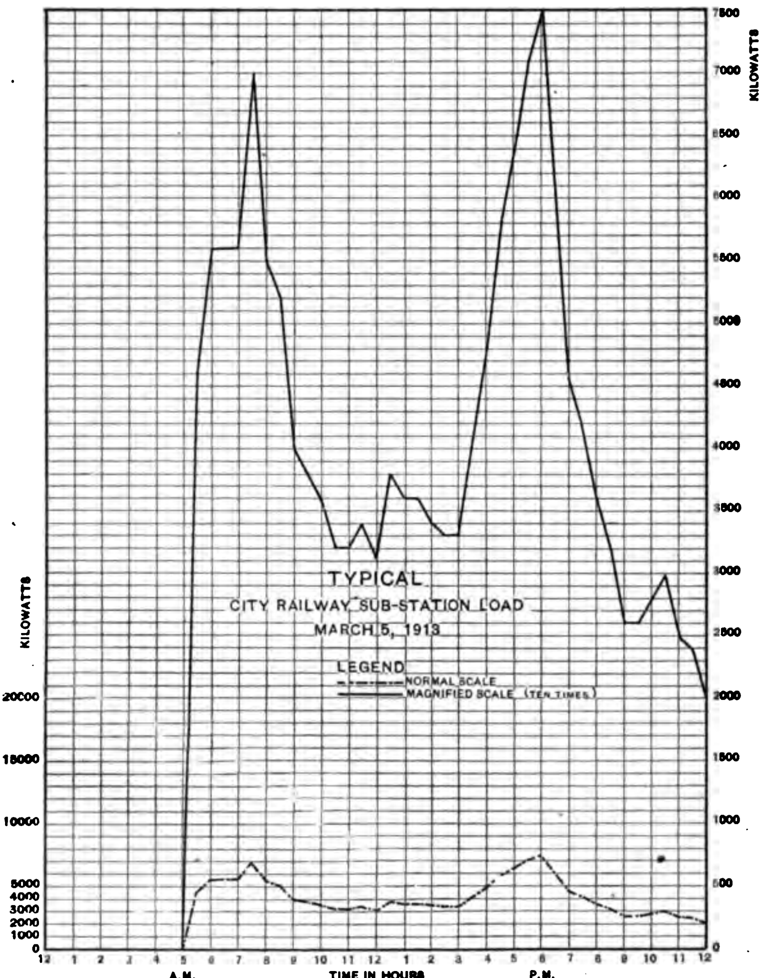


FIG. 4—TYPICAL CITY RAILWAY SUBSTATION LOAD

one control, furnishing light and power to large areas from one central point, we find a growing tendency to take on railway loads as well and furnish power for the entire field from one source.

This change has been made possible not only by economic reasons but in a large measure by improvements in 60-cycle conversion apparatus, such as rotary converters. The modern 60-cycle rotary converter is now a thoroughly reliable piece of apparatus and is available in sizes as large as conditions require. There are now in service a number of 2000-kw. 60-cycle rotary converters on railway systems.

Two instances may be of interest as illustrating the marked tendency of the light and power requirements to dominate those of the railway. In one case a well established traction company operating on a 25-cycle system began an active campaign for extension in the light and power field throughout its territory. To-day, practically all the 25-cycle apparatus—both generating and substation—has been replaced by 60-cycle and the entire system is

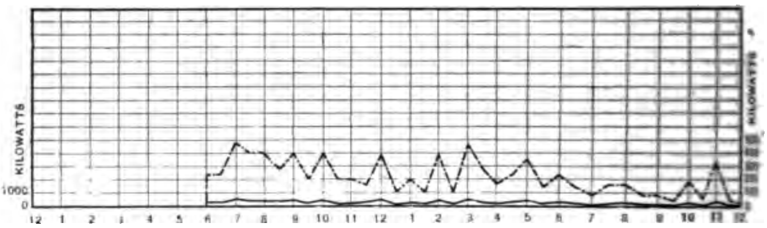


FIG. 5—TYPICAL CITY RAILWAY SUBSTATION LOAD

now on a 60-cycle basis. In another case, a railway company decided to put in a new power system, selecting 25 cycles as the frequency, due to the importance at that time of the railway load. Plans were made to extend over a considerable area and take over numerous towns, going after the power market. When a careful study of the possibilities was made it was found that the light and power load would in a very short time outstrip the railway load and that to give service from the new power system would require a heavy investment in frequency changers, with the resulting losses of transformation. The outcome was a decision to change the frequency to 60 cycles. Apparatus was accordingly ordered and installed for the higher frequency and is now carrying the combined load with entire satisfaction.

Motor-generators were formerly utilized on 60-cycle systems in preference to rotary converters, but with the improvements in

the latter, equally reliable operation can be secured with decided advantages in favor of the rotary converter.

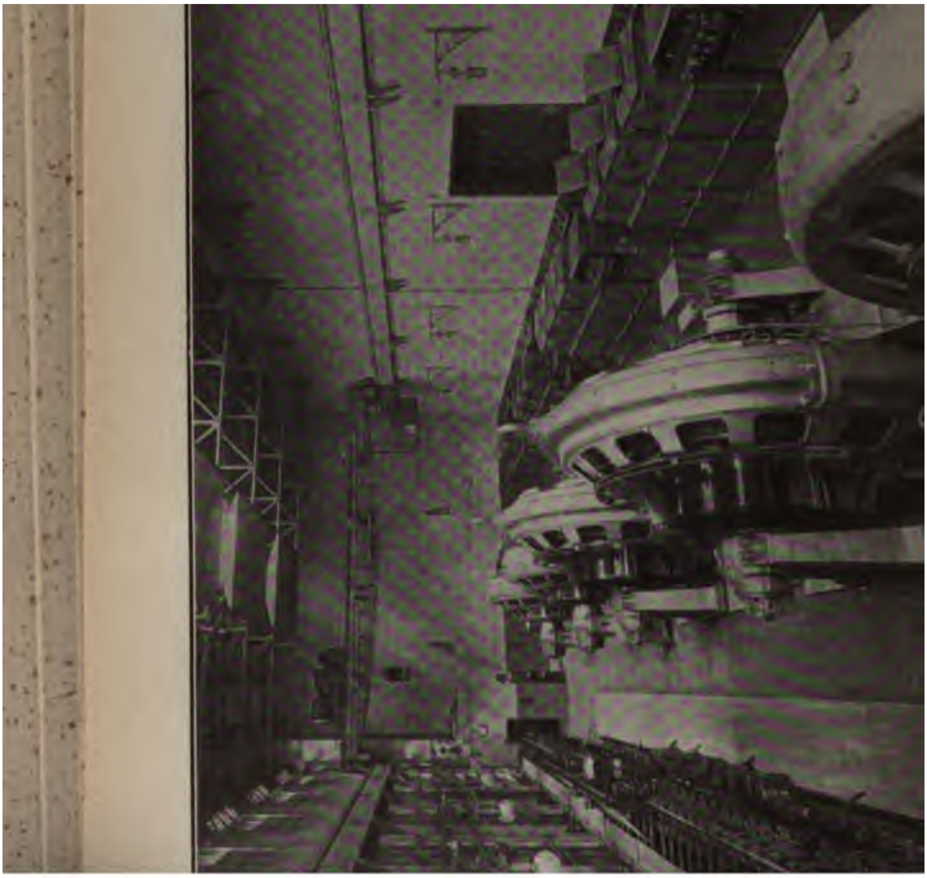
Efficiency is an important factor, especially where power is purchased. Comparatively, the efficiencies of a 1000-kw. 60-cycle motor-generator set and a 1000-kw. 60-cycle rotary converter with transformers show the difference in favor of rotary very clearly.

	1/4	3/4	4/4
1000-kw. rotary converter and transformers ...	89.7	92	92.2
1000-kw. synchronous motor-generator	84.7	88.4	89.8
Difference	5	3.6	2.4

FIG. 6—WINDMERE SUBSTATION, CLEVELAND RAILWAYS CO., 1500-KW. 60 CYCLE ROTARY CONVERTERS

Railway apparatus operates a large part of the time at less than full load and the efficiencies noted in the table show the favorable results of rotary converter at the lighter loads.

Power factor is now recognized as a very important matter. The synchronous motor-generator is commonly believed to be



al for operation at unity power factor or for operation with ding current to correct for low power factor. The apparatus do all this if properly operated, but unless closely looked r will not inherently give such desirable results. In other rds the field of the motor must be adjusted at all changes of ad, and this can be done, if necessary, by an automatic regulator.

The rotary converter, on the other hand, may be so proportioned that it can be automatically operated at an average power factor very close to unity. In one substation containing three 1500-kw. rotary converters on a regular city railway ad, the average power factor for several months has been ove 99 per cent. Equally good results have been obtained in her substations.

In submitting a proposal to sell power to a railway company e rate offered should be determined only after a very careful udy of the problem. While the average railway company is ore of a transportation specialist than a power specialist, and e central station is the latter, still a well-organized railway mpany knows the game pretty well and is doubtless in a position to state its costs and what it can afford to pay for power. n other words, where a railway company has a power station n good operating condition it will be a difficult matter for the entral station to make a rate which will warrant shutting down he power plant and still yield a revenue profitable to the central tation. A careful analysis and study will, however, in many cases ring out conditions which would make the purchase of power by the railway company desirable and profitable to both parties to the contract.

In general, the advantages of railway load to the central station are:

A single customer taking a large block of power.

Improvement in load factor of the system.

Load carried at high power factor.

A customer having generally a growing business.

A customer of known credit.

One important favorable result in carrying combined light, power and railway loads on one station or system is the possibility of utilizing larger units with their corresponding increase n efficiency of operation, and reduction in the cost of unit production.

As stated in the beginning, it cannot be assumed that central station can take over the railway load of the terri serves, but it is the opinion of the writer that the electr ways offer to central stations a very profitable field for sales and one that has not as yet received the study its imp merits.

The writer wishes to express his thanks and appreci the operating engineers who have so willingly furnish and information, making possible the presentation of thi

THE CHAIRMAN: Mr. Dillon's paper is now open cussion. If there be no discussion we will hear the pa pared by Mr. W. A. Darrah, of Pittsburgh, on Late D ments in the Flame Carbon Arc Lamp.

LATE DEVELOPMENTS IN THE FLAME CARBON ARC LAMP

As a result of the growth and development of our larger ities and the broader understanding of the principles of prosperity which is rapidly being acquired by business men, there has arisen an insistent demand for more and better light. This is an important factor in community life to-day. Towns which a few years ago were contented with barely enough street illumination to avoid obstacles are now insisting on having each business thoroughfare a "Great White Way," while the little villages which existed entirely without street lights until lately, have now realized the money value of illumination and are rivaling each other and even larger towns in an abundance of street illumination.

Naturally, the new demands have been for larger and more efficient lighting units, for apparatus which will produce the required light flux with the minimum of cost and the maximum of reliability. In the present instance the industry has kept pace with the demands, and the long-burning flame carbon arc lamp is the result.

It is the purpose of this paper to consider briefly some of the problems which have been solved in commercializing a lamp of this type. The problems will be considered from the point of view of the operating man with the idea of indicating what performance and service may be expected from a flame carbon arc lamp.

The flame carbon arc lamp is a large energy unit, in the sense that the high electrical and luminous efficiencies and the large light flux are obtained with between 440 and 600 watts at the terminals. It is somewhat more efficient on alternating-current circuits than on direct-current circuits, but operation is equally reliable and satisfactory under either condition. From 25 cycles to 130 cycles, and even higher, the light is intense and free from excessive flicker, while the life per trim is long and the operation, therefore, economical. Because of these characteristics, a flame carbon arc lamp is peculiarly adapted to the lighting of streets, large areas, factories and shops. In other words, the flame car-

bon lamp is equally satisfactory wherever a large energy unit is required, either out or indoors.

In passing upon the degree of success with which any kind of apparatus operates, it is necessary to have some criterion and a well-defined idea of the operating conditions and requirements. From the standpoint of operating conditions it seems safe to say that the arc lamp is without exception given less attention and is subjected to more severe service and more abuse than any other piece of commercial electrical apparatus. It is at once a chemical laboratory, an electric furnace, a nicely balanced mechanical device and an electrical machine, which is alternately frozen and baked, well saturated with water and entirely dried out. These service conditions added to the effects of the weather, make an arc lamp, unless properly and well constructed, subject to unusually heavy depreciation. It is, therefore, imperative that the central-station engineer satisfy himself that the design and construction of the lamp are satisfactory, and that the factors of safety are ample.

Briefly stated, the essential requirements are in the order of their importance: First, reliability; second, minimum demand for attention; third, economical and satisfactory performance, and fourth, satisfactory illumination.

Leaving aside the consideration of carbons, which has been previously treated,* these requirements may be classed as mechanical and electrical features. While the operating engineer usually and rightly stops with the enumeration of these points, it becomes the work of the designing engineer to analyze each requirement into its elements and to make certain that his design will meet the service demands.

An analysis, then, of the requirements given shows that on the mechanical side, to cover the first and second essentials, the construction should be weatherproof, that all parts should be made from materials which are not subject to appreciable deterioration under service conditions, and that friction must be kept at a minimum, initially and after severe service.

To secure a maximum of reliability with minimum attention, as well as economical and satisfactory performance from the electrical side, operating temperatures should not be excessive, the

*See a paper presented by the author before the joint meeting of the A. I. E. E. and I. E. S. at Boston, February 17, 1913.

potential strains should be minimized, the margins of insulation should be large, and the insulating material should be fireproof and weatherproof.

Theoretically, the problem appears simple and the rules are almost self-evident; actually the problems are rather complicated, and the final commercial design is the result of a judicious bal-

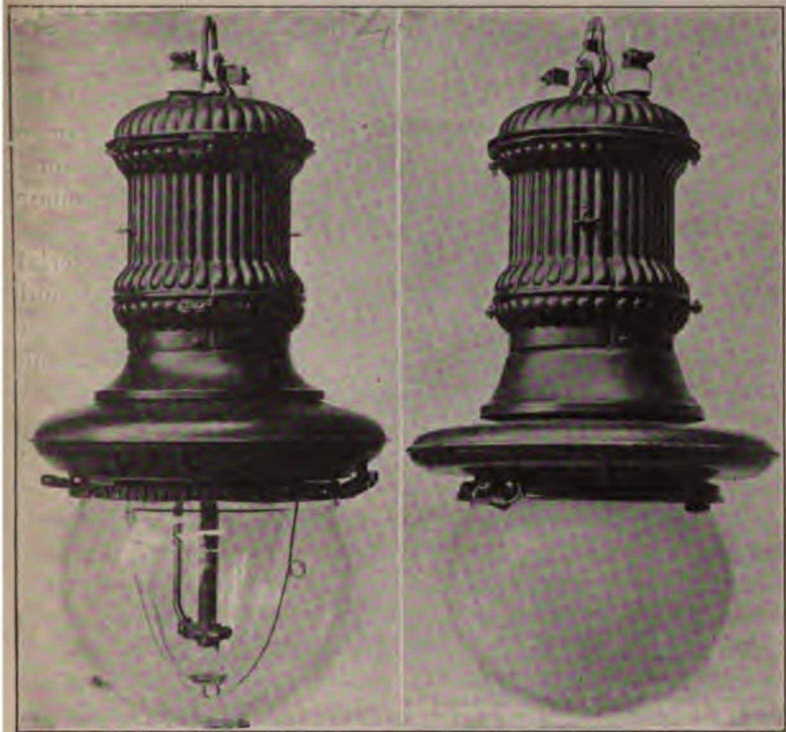


Fig. 1

B — New Type — Note Thick Condensing Chamber

A — Old Type — Note Thin Condensing Chamber

ance of operating requirements against the commercial condition surrounding the manufacturer of a commercial device of this type.

The consideration of a mechanical design may be divided broadly into statics and dynamics.

Under the heading of statics is included the design of such parts as a lamp case and the part of the lamp structure which does not move during the operation of the lamp. It has been found that the material of an arc lamp case must be durable in itself, as no commercial finish at present known to the industry can be relied upon to protect the metal within. The causes for the deterioration of alloys and metals of that nature are many, mainly corrosion caused by acid fumes and the weather, and the continuous alternate heating and cooling through a rather wide range, which destroy the fiber of the metals. Aside from considerations of materials, the disposition of the material must be correct. The shape should be such that the case will be at once light and strong, the material must be used economically, while a graceful and pleasing appearance is by no means a minor consideration.

A good example of two ways in which the same material may be employed with very different results as to strength and appearance is shown in Fig. 1. A represents the flame carbon lamp in the process of development, while B shows the same lamp after development has been completed. It will be noted that by increasing the height of the condensing chamber and giving it slightly more arch its appearance was materially improved and the strength of the whole considerably increased.

A further rather important consideration in connection with the lamp case is accessibility. It is essential to economical operation that free access be possible at all times to the interior of the case. This is at present accomplished commercially in two ways: either by the bayonet type of sliding case or by the use of doors. Both methods are satisfactory, although it is probable that doors afford somewhat more convenient access to the mechanism. Whether doors are provided or the case is opened by telescoping sections, it is essential that the proper overlap be provided to prevent rain or snow from entering under any conceivable condition of eddying winds. Fig. 2 shows how this may be accomplished. With the amount of overlap and with the spring fastening shown, it is possible to draw the two sections together so tightly that the case is entirely weatherproof.

These general statements made regarding the service conditions and requirements of the case apply with much more force to the condensing chamber of a flame carbon arc lamp, which

is subjected to higher temperatures than the remainder of the case, as well as to excessively corrosive hot fumes from the arc. In addition, all joints in the condensing chamber must be absolutely

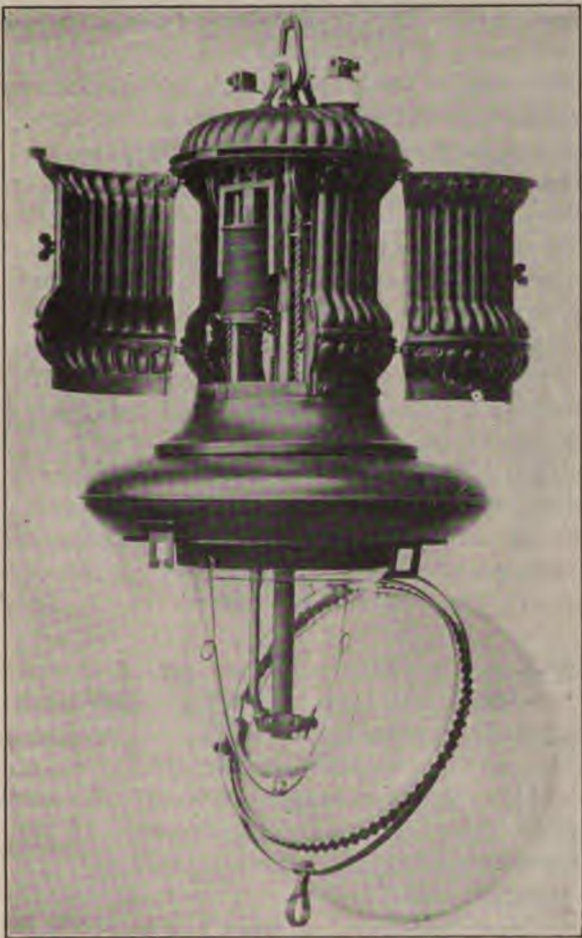


FIG. 2

air and water tight, as the unintentional admission of very slight quantities of either air or water will reduce the life of the carbons by a large percentage.

Because of the necessity of keeping all the joints in the condenser chamber tight, it is desirable that this part of the lamp

be removed as seldom as possible. This may be secured by making its removal relatively inconvenient. Since there are very few occasions requiring its removal this is a satisfactory expedient.

A final subject which deserves some consideration under the heading of statics is the material from which the strap, rods and punched parts of the lamp are made. Experience has shown that punched or rolled alloys are often unreliable, due to the decay of the fibers under the heat treatment to which they are subjected if stretched or drawn to any degree in forming. Copper or phosphor bronze has been found most satisfactory for these parts, although it appears that brass castings or plates are not subject to the fiber failure. Alloys which have failed in this manner have a rough surface and may be broken in the fingers.

Of perhaps greater importance than the structure of the lamp is the design of its mechanism from a kinematic point of view. Keeping in mind the requirements previously noted of reliability and low maintenance cost, the subject of friction in feeding and regulation deserves considerable attention, for unless a lamp is properly designed depreciation will first become evident, aside from actual failure of the component parts, in excessive friction, which will result in unsatisfactory regulation, a flickering light with frequent feeding, and an unduly large outage report.

Friction may be of two kinds: (1) fixed, or that which is initially inherent in the lamp and will not appreciably increase in amount, and (2) progressive, which will increase in service under corrosion, accumulation of grit, gum, etc. Knife-edge friction, and the rotation of relatively large wheels on small axles, are examples of the first or fixed friction, while all sliding parts, as the movements of carbon holders on stationary guides come within the second class.

It is evident, therefore, that while in a new lamp the relative values of fixed and progressive friction are of little importance, this point becomes vital after the lamp has been in service for a few years. It should be noted that friction does not directly reduce the efficiency of an arc lamp, as in moving machinery, by consuming energy, but in a more subtle way. Larger margins are required and therefore there are larger continuous losses where friction is high.

Fig. 3 shows diagrammatically one form of lamp mechanism signed to eliminate entirely sliding friction during the regula-

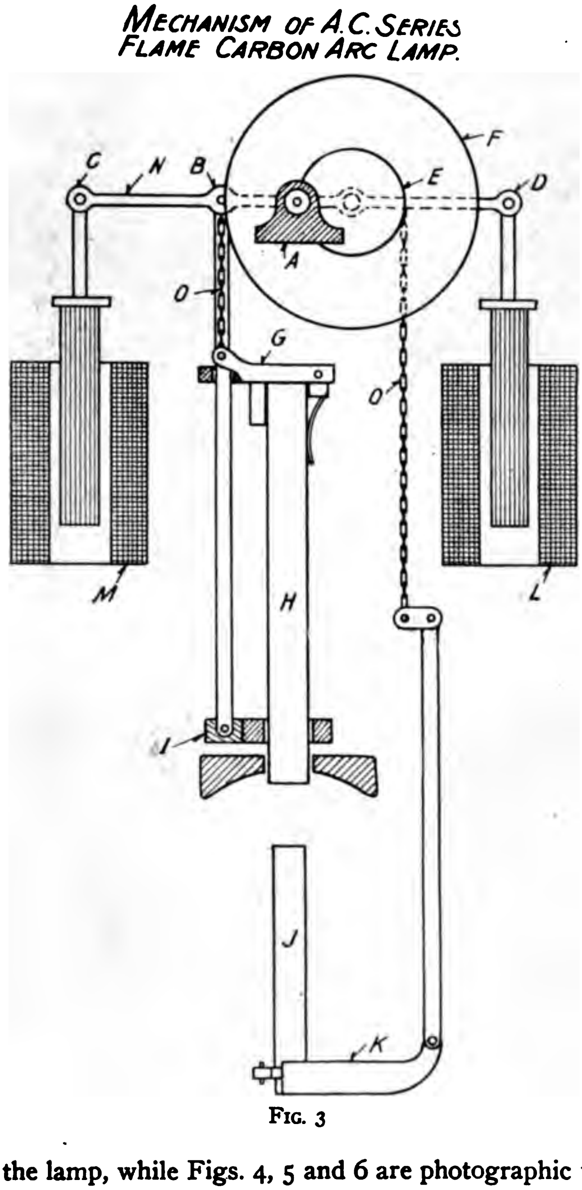


FIG. 3

on of the lamp, while Figs. 4, 5 and 6 are photographic views of ich a mechanism.

It will be noted from Fig. 3 that the rocker arm N, wh
is pivoted at A, carries the bearings for the chain wheels, E
F, the clutch rods, B, and the magnet cores, C and D.

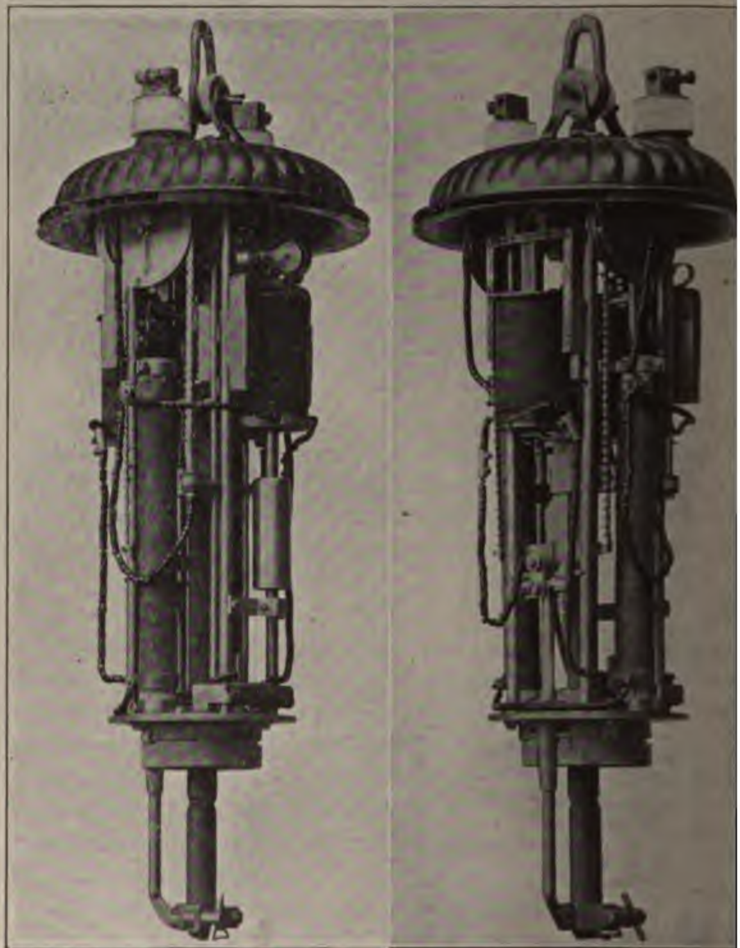


FIG. 4

The chain wheel F, which carries the upper carbon ho
is so placed that the chain O, which supports the upper ca
holder, leaves the wheel in the same vertical plane that con

the clutch rod. Since the regulation of the lamp is accomplished by the rocking of the rocker arm N, there will be no relative

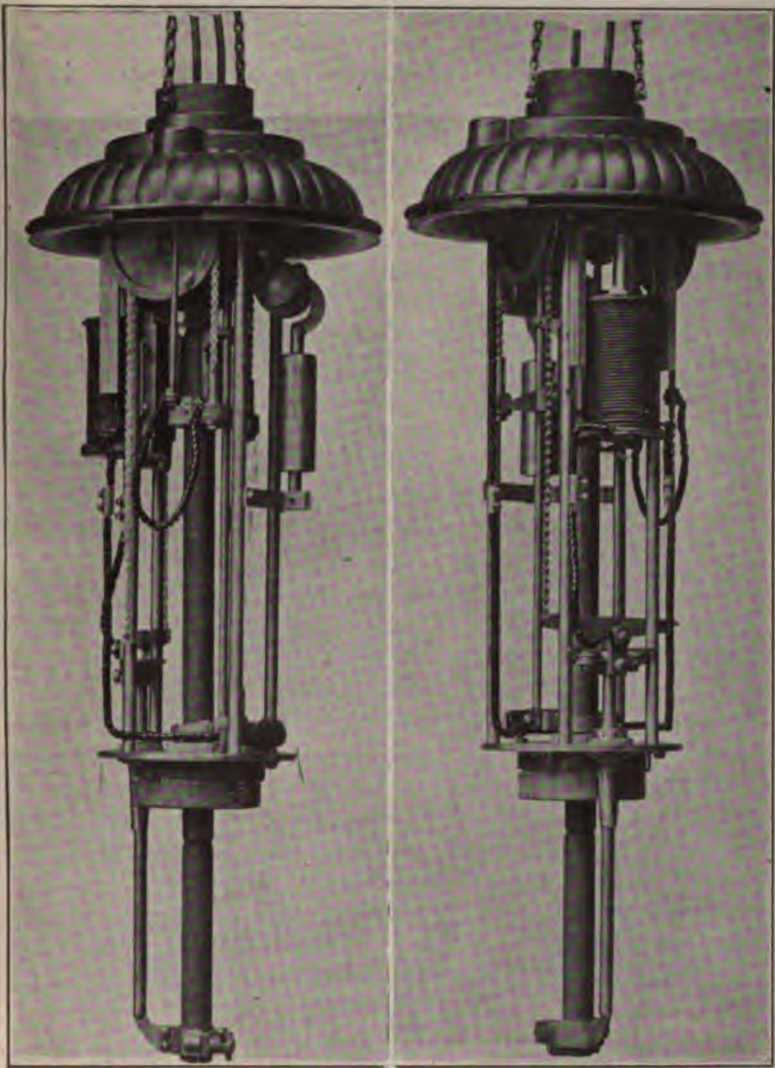


FIG. 5

movement of the clutch rods and the chain which holds the upper carbon holder. If, therefore, the clutch rods are made

the only guides of the upper carbon holder, the sliding friction during regulation is eliminated.

This mechanism also automatically compensates for the effect of changes in weight of carbons on the voltage.

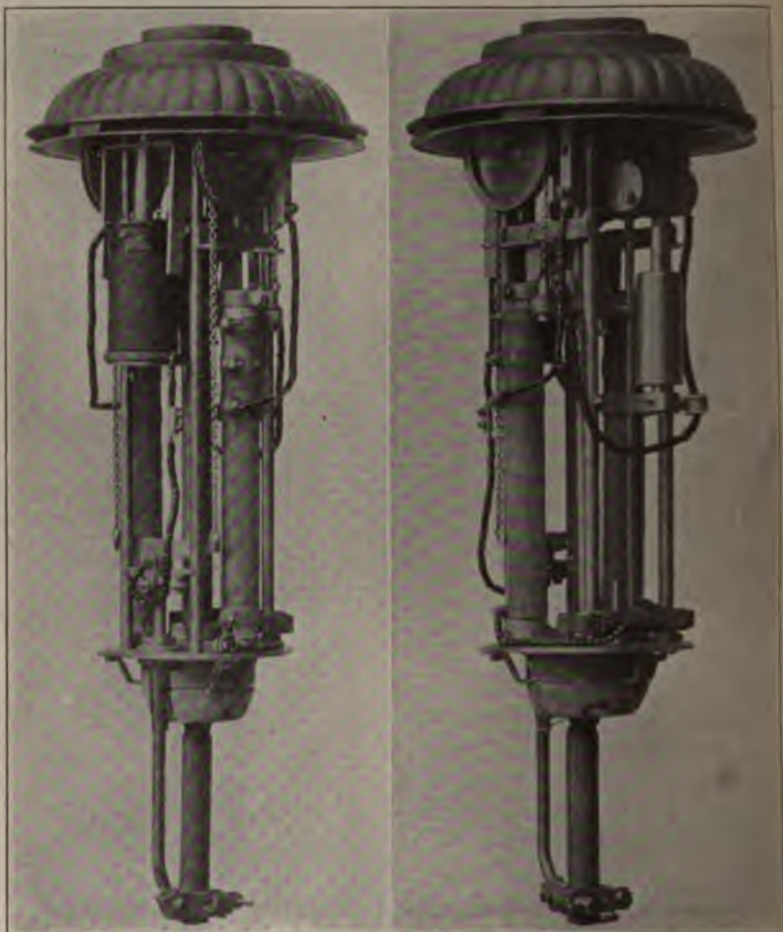


FIG. 6

Figs. 4, 5 and 6 show how this has been accomplished.

It will also be noted that this method of eliminating the sliding friction of the upper carbon holder, which is the vital spot of an arc lamp, also permits the use of the ring clutch.

Aside from the effects of friction, an unreliable clutch can probably cause more trouble than any other mechanical fault. The ring clutch, if properly constructed from hardened steel to prevent wear, offers probably the maximum of reliability, providing the carbon manufacturers can insure a uniform diameter in their product. Since both American and foreign manufacturers can guarantee a variation in carbon diameter which is well within the limits of operation of even a badly worn ring clutch, it is possible to secure the reliability and satisfactory operation of this device.

The value of an arc lamp depends upon the intensity and steadiness of its light. A flickering arc lamp is one of the worst illuminants imaginable because of the very intensity of its light. To secure steadiness and freedom from variations of light intensity, it is essential that the regulation be as perfect as possible, therefore the importance of the subject of regulation should be borne in mind. Since the light from a flame arc comes largely from the flame and only slightly from the carbon terminals, the length of the flame should be as uniform as possible. However, the long arc causes continual instantaneous changes in current density and arc composition and these demand that the mechanism continually adjust the arc length to these changes, in order to maintain the arc and to prevent flickering. This requires that a flame carbon arc lamp be designed to secure more perfect regulation than the former types of lamps.

Fig. 7 shows typical regulation curves of a series alternating-current flame carbon arc lamp. These are plotted between carbon separation as abscissa, and voltage across the shunt coil as ordinates. Curves A and B show the regulation of a carbon clutch lamp with the carbons separating and moving together respectively, while curves D and C give similar data on a lamp of the same rating and general characteristics, but operated by a drum clutch.

Since in the range considered, the voltage on the shunt coil is approximately proportional to the pull of the shunt coil, the regulation curve here given is an indication of the force required to hold the rocker arm at any given angle, but in consuming the carbons the rocker arm moves through all possible positions between each feed of the lamp. Therefore, to maintain a uniformly long arc at all times it is essential that the regulation

curve be as nearly horizontal as possible throughout the operating range of normal carbon separation. It will be noted that curve A which is taken from the operation of the carbon clutch lamp is substantially horizontal through the normal working range,

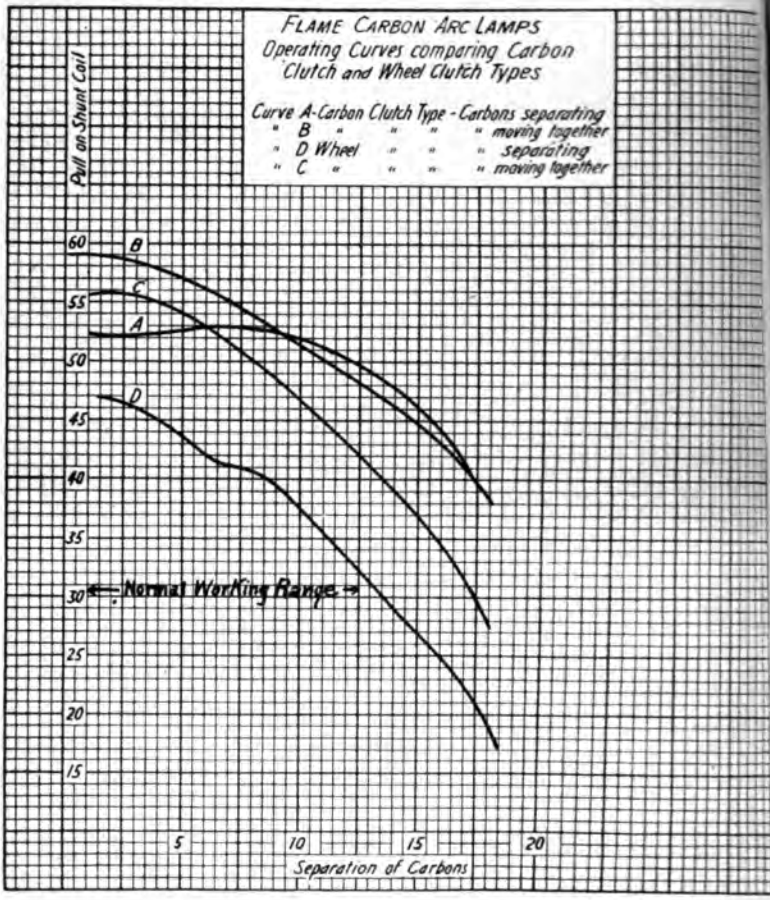


FIG. 7

thus indicating that the arc voltage and therefore the light is constant.

Referring to previous comments on the effect of friction on the regulation of a lamp of this type the curves given in Fig. 7

neasure of the regulating friction of a lamp. Thus, if is secured by noting the pull necessary on the shunt to allow the carbons to separate, and curve B by noting which allows the carbons to fall together, the difference curves A and B in a vertical line, measures the friction

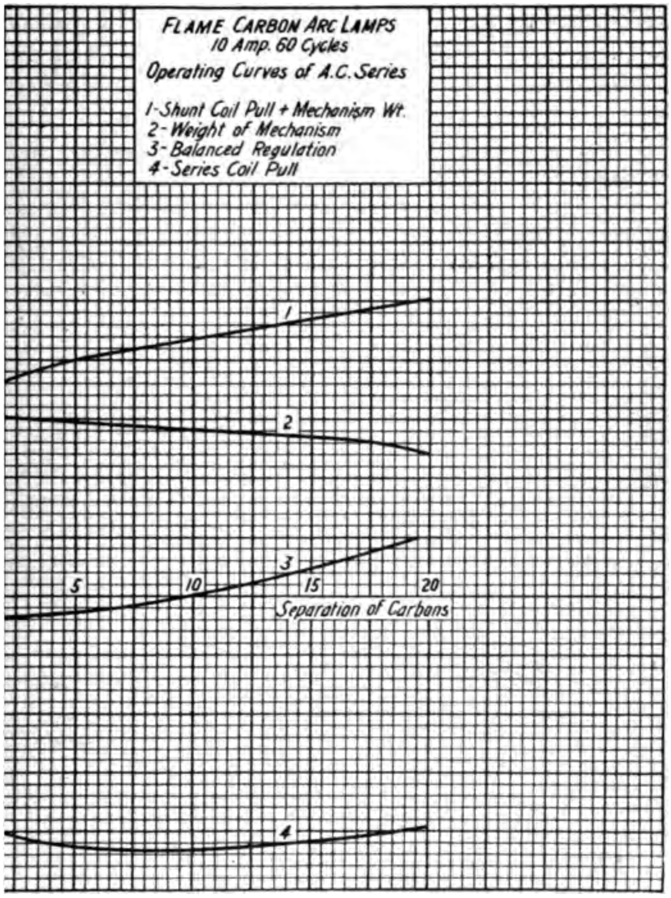


FIG. 8

in the lamp. It is interesting to note that in the carbon mp, because of the arrangement of mechanism previously l, the friction is actually zero at some points and neg- ; most others.

Fig. 8 shows curves similar to curve A of Fig. 7, but plotted between carbon separation and mechanical pull. In Fig. 8, curve 3 shows the pull necessary to hold the rocker arm in any given position with the normal current and voltage on the lamp. In other words, it is a "stability" curve of the regulation, and the point at which it crosses the zero line is the carbon separation at which the lamp will normally operate. A stability curve similar to the one here shown indicates that only a weak dash pot is needed, as the lamp will not be unstable.

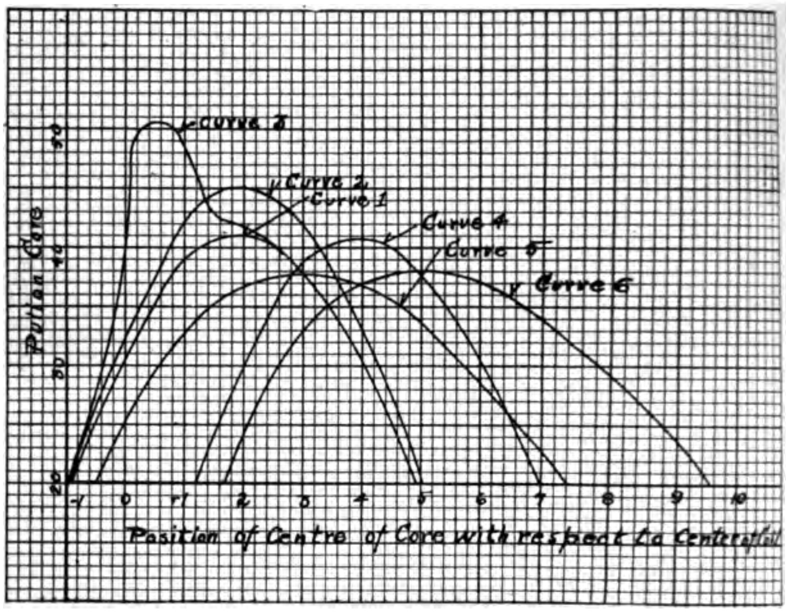


FIG. 9

Curve A, Fig. 7, shows the pull of the mechanism and the so-called overbalance, or the tendency of the carbon to feed together, due to their own weight when no current is flowing in either coil.

Curves 1 and 4, Fig. 8, show the variation of the shunt and series coil pulls respectively with the rocker arm and therefore the cores in various positions. The final regulation curve of the lamp, curve 3, is the algebraic sum of curves 1, 2 and 4.

Fig. 9 shows how the shape of the pull of a coil on a straight iron core can be varied to produce any degree of regulation desired. Curve 1 represents the normal curve of a straight coil and core without iron on the spool of the core.

Curve 2 shows the effect of more iron in the core, while curve 3 shows the effect of adding iron washers to the lower end of the coil spool. Curve 4 shows the effect of lengthening the core without changing the coil, curve 5 the effect of lengthening the coil without the core while curve 6 shows the effect of lengthening both. It will therefore be seen that when properly handled the pull of a solenoid is an exceedingly flexible quantity and that therefore by the proper design almost any desired regulation can be secured.

The points enumerated cover but a small part of the consideration which should be given to an arc lamp design. In spite of the seeming simplicity of the lamp and the apparently simple task that it has to perform, its design and construction call for a degree of engineering skill and experience not less than for the largest or most expensive piece of electrical apparatus. Engineering progress, however, has more than kept pace with the requirements of the industry, and to-day, the flame carbon arc lamp inaugurates a new era in lighting and lighting units which will undoubtedly displace the older units to a large degree.

DISCUSSION

Mr. Charles Field, Cleveland (submitted in writing):

(1) In the last paragraph, on page 713, it is stated that "the flame carbon arc lamp is somewhat more efficient on alternating-current circuits than on direct-current circuits, but operation is equally reliable and satisfactory under either condition." The writer evidently refers to overall efficiency, and while this statement is probably true, in this connection, it should be noted that when luminous efficiencies are considered a direct-current arc is more efficient than an alternating one. This is especially emphasized by the results obtained from recent developments in yellow carbons.

(2) The last paragraph, on page 716, reads: "These general statements made regarding the service conditions and requirements of the case apply with much more force to the condensing

chamber of a flame arc lamp, which is subjected to higher temperature than the remainder of the case, as well as to excessively corrosive hot fumes from the arc." In this connection it should be stated that carbon development work is now in progress, whereby a commercial carbon has been produced in which the corrosive fumes are largely reduced. This carbon will probably materially lessen the deterioration in glassware and condensing chamber.

(3) Referring to the diagram, Fig. 3, it will be interesting to know what provision has been made to compensate for the loss of weight in the carbons due to their consumption. For instance, the total carbon length at the commencement of the trim is approximately 18 in. to 20 in., while near the end of the trim the total length of carbon is approximately 8 in.

A few considerations in carbon performance may be noted:

(a) A point of extreme importance is the magnetic blow, and lack of attention to this point is liable to introduce slagging and other troubles which would reflect unjustly on carbon performance.

(b) An improper alignment of upper and lower carbons will also produce similar slagging effects.

(c) Another point to which careful attention should be given is the proper enclosure of the arc and the maintenance of tight joints at all parts. A very large proportion of the outages, slagging and short carbon life is due to poor enclosure, careless trimming and improper magnetic blow.

MR. A. L. LOIZEAUX, Baltimore: Mr. Darrah states that the arc lamps described in his paper do not give excessive flicker on 25 cycles. If it be true that an arc lamp has been developed which can be generally used with satisfaction on 25 cycles, every one should know it, as it would mean an important step in lighting economy. There are a great many companies operating 25-cycle generating systems, and these companies, as a rule, operate their arc lamps by means of mercury-arc rectifiers, using magnitite or other direct-current lamps. This method is much more expensive than the use of constant-current transformers alone, because the constant expense of rectifier tubes would be avoided. The operation of constant-current transformers is also simpler and less liable to interruption than the mercury arc rectifiers.

For the reasons mentioned, we have been on the look-out for a satisfactory 25-cycle arc lamp, and we have tried many new

lamps of this type. It is a matter of personal opinion, perhaps, whether the flicker is excessive or not, but it has been the unanimous opinion of members of our company who have looked at the 25-cycle lamps in operation, that they were entirely unsatisfactory for general use, due to the pronounced flicker. The older carbon lamps made for 25-cycle are extremely bad, and the later flame-type, 25-cycle lamps, while much better, are still open to serious criticism. If the author's statement that the new lamp is satisfactory on 25 cycles proves correct as a general fact or opinion, the lamp should be a real help to the lighting industry.

MR. DARRAH: The flame carbon arc lamp is materially better than the enclosed carbon lamp in the matter of flicker on low-frequency circuits. What may be called excessive flicker is a matter of opinion. It has been our experience that the flicker from a 25-cycle lamp is satisfactory in commercial shops and factories, and we have several installation of that kind now in operation. It must be admitted that the flicker from a 25-cycle lamp is appreciable, and by waving your hand about in the lighting, or by watching rapidly revolving wheels, the effect of the frequency can be noted.

THE CHAIRMAN: The next paper on the program is that by Mr. T. K. Stevenson, of New York City, on Overhead Distribution Circuits for Series Arc Lighting.

OVERHEAD DISTRIBUTION CIRCUITS FOR SERIES ARC LIGHTING

There are many factors to be considered in determining the proper and economical size and type of wire which will be the most efficient conductor for any given overhead circuit. Most of these various factors, however, will group themselves into two separate and distinct classes—first, the electrical requirements as to conductivity, and secondly, the mechanical requirements as to strength.

These two requirements have, generally speaking, but little or no relation to each other. Under one condition it may be that high conductivity is of great importance and but little strength is needed; while for another circuit, strength and security may be the governing features.

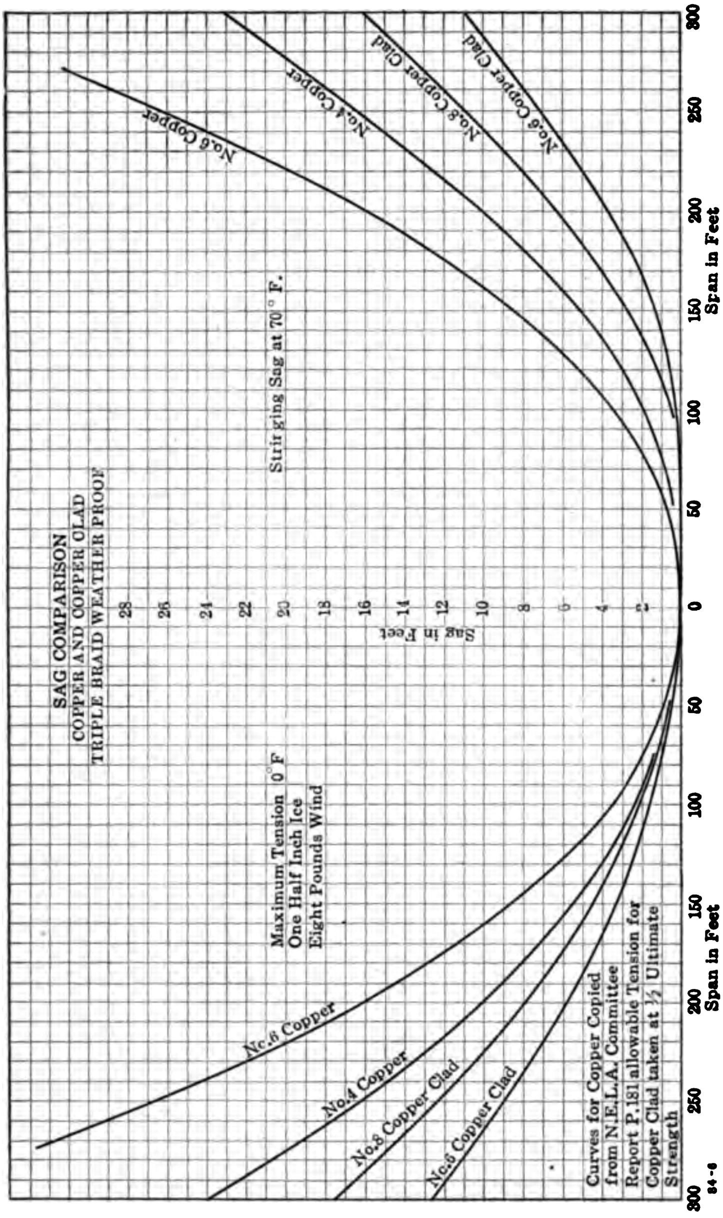
As a result, if there is but one material of construction available, such as copper, in which any size of wire of a given conductivity has a certain fixed maximum of strength, it would be a rare coincidence that the same size of wire would give just the required strength and just the required conductivity. Almost always it would happen that either the wire with just sufficient conductivity is not sufficiently strong, or the wire with just sufficient strength has not sufficient conductivity.

It is, therefore, of importance to determine what available material has the most desirable ratio of strength to conductivity and whether such a material will give the most economical construction and operation.

There are four types of wire commercially manufactured that could be used for overhead circuits—aluminum wire, copper wire, iron wire and copper-clad steel wire.

As this paper is especially concerned with distributing circuits, and as triple braid weatherproof wire is almost universally specified for this purpose, this material will be considered in the following discussion.

Weatherproof aluminum wire is more expensive than weatherproof copper wire per unit of conductivity, not to speak of its low tensile strength and the special care necessary in its handling.


SAG COMPARISON
COPPER AND COPPER CLAD
TRIPLE BRAID WEATHER PROOF
Stringing Sag at 70° F.
Maximum Tension 0° F
One Half Inch Ice
Eight Pounds Wind
Curves for Copper Copied from N.E.L.A. Committee Report P. 181 allowable Tension for Copper Clad taken at ½ Ultimate Strength
Sag in Feet
Span in Feet
No.6 Copper
No.4 Copper
No.8 Copper Clad
No.6 Copper Clad

Weatherproof iron wire also is more expensive per unit of conductivity than copper, even in direct-current circuits, and in alternating-current circuits its resistance is greatly increased by skin effect. Moreover iron wire has not a high strength, having a tensile strength of only about 55,000 lb. per sq. in.

Weatherproof copper wire is without doubt the most economical material to use if conductivity alone is considered, but it has a very low tensile strength. Even hard-drawn copper wire has only 60,000 lb. per sq. in. tensile strength, but, unfortunately, hard-drawn copper has the disadvantage of breaking easily if nicked or kinked, and has to be handled with great care. As a result, its use has been practically abandoned for distributing circuits and annealed copper wire is now used, which has a tensile strength of only 34,000 lb. per sq. in.

Copper-clad steel wire is commercially manufactured in three electrical grades having a conductivity respectively of 30, 40 and 47 per cent of copper. Its tensile strength varies somewhat with the size and is about 88,000 lb. per sq. in. in No. 6 B. & S. It has the further advantage over copper of being practically non-stretching, its elastic limit being very high, from one-half to two-thirds its breaking weight,.while annealed copper has practically no elastic limit, as it begins to stretch under very small loads when applied for a long time. The result is that copper wire must frequently be pulled up to take the excess sag out of the span and this soon stretches the wire. This stretching of the wire is one of the most potent causes of the tearing and failure of weatherproof insulation.

Copper-clad wire will not permanently stretch but will return to its original sag after any applied load within the elastic limit is removed. It does not have to be pulled up and, therefore, the weatherproofing on it lasts longer.

The coefficient of expansion of copper-clad wire is 0.000012 per degree centigrade. This is about one-third less than copper wire and therefore the sag of copper-clad wire at different seasons of the year is much more uniform than that of copper.

The elastic limit, modulus of elasticity and coefficient of expansion are all different from the corresponding properties of copper and these differences are such that the corresponding sags for copper-clad are in every case much less than for copper wire. It

s, therefore, advisable when both copper and copper-clad conductors are carried on the same pole to put the copper-clad wire on the upper cross-arm.

In considering these various conductors, weatherproof aluminum and iron can be eliminated as being more costly than copper and having no compensating advantage. There remains, therefore, copper and copper-clad steel conductors for comparison.

If a copper wire of any given size be considered and still more conductivity is required, it is the natural and logical procedure to use a larger copper wire, for copper has the highest conductivity commercially available, but if more strength is required it is not logical to use a larger copper wire, for copper has not a high strength. It is much more reasonable to reinforce the copper wire with some strong and cheap material. Steel costs per unit of strength approximately 1/25th as much as copper, and is the most available material for such a reinforcement. Copper-clad steel wire, therefore, is the combination of copper, which is the cheapest form in which conductivity can be obtained, and steel, which is the cheapest form in which strength can be obtained.

Copper-clad steel wire is reinforced copper wire. It is a wire for use under conditions where strength is a factor of importance.

There are a number of conditions in the lighting field where strength is the governing feature in the determination of the size of wire. The most self-evident case is the series arc and incandescent circuit. The majority of series arc lamps now in service take from 4 to 7.5 amperes and the tendency in new construction seems to be toward the lower of these values. The National Electric Light Association rates the safe carrying capacity of even a No. 14 copper wire at 10 amperes, and yet when it comes to overhead construction specifies that no wire shall be used of less strength than No. 6 copper. In other words, the copper wire of sufficient strength in this case has six times the required carrying capacity.

As a matter of fact, some of the larger companies are going even further and are specifying nothing smaller than No. 4. Below is a comparison of the electrical and mechanical properties of Nos. 4 and 6 copper wire and Nos. 6 and 8 copper-clad wire.

	No. 4 B & S Annealed Copper Triple Braid Weather-proof	No. 6 B & S Annealed Copper Triple Braid Weather-proof	No. 6 B & S Hard Drawn Copper Clad Triple Braid Weather-proof	No. 8 B & S Hard Drawn Copper Clad Triple Braid Weather-proof
Weight per mile, lb.	865	590	560	376
Breaking weight, lb.	1,114	700	1,800	1,200
Resistance per mile, ohms.	1.33	2.11	4.63	7.42
Price per lb.	\$0.17	\$0.17	\$0.16	\$0.16
Cost per mile	147.05	100.30	89.60	60.16

The above comparison is made between annealed copper wire, which has been the standard for lighting circuits, and hard-drawn copper-clad wire. Hard-drawn copper-clad wire can be handled without trouble or special care as the strength is in the steel core and surface nicks do no harm. However, if soft-drawn copper-clad wire is desired, it can be furnished in any state from dead soft to full hard, and even in the annealed state is as strong as copper wire two gauges larger.

Below is given a comparison of the financial results that should be obtained from the use of the above sizes of wire based on a 4, 5 and 6-ampere circuit. The life of both wires is assumed to be 15 years, though that of copper-clad should be longer than that of copper wire.

	No. 4 Copper	No. 6 Copper	No. 6 Copper Clad	No. 8 Copper Clad
Weight per mile, lb.	865	590	560	376
Price per lb.	\$0.17	\$0.17	\$0.16	\$0.16
Cost of wire per mile	\$147.05	\$100.30	\$89.60	\$60.16
Weight of scrap metal	666	419	390	245
Price of scrap	\$0.13	\$0.13	\$0.035	\$0.035
Value of scrap	\$86.58	\$54.47	\$13.65	\$8.57
Net depreciation	\$60.47	\$45.83	\$75.95	\$51.59
Annual charges:—				
Interest and taxes at 8 per cent.	\$11.76	\$8.02	\$7.17	\$4.81
Depreciation, 15-year life	4.03	3.06	5.06	3.44
	\$15.79	\$11.08	\$12.23	\$8.25

On the basis of a 4000-hour schedule, and taking the cost of power at 0.5 cents per kilowatt-hour, the I^2R loss per mile of wire per year is as follows:

	No. 4 Copper	No. 6 Copper	No. 6 Copper Clad	No. Copper Clad
4-Ampere circuit	$0.43	$0.68	$1.48	$2.38
5-Ampere circuit	.67	1.06	2.32	3.73
6-Ampere circuit	.96	1.52	3.34	5.34

Adding this loss to the annual charges as above gives the following cost per year:

	No. 4 Copper	No. 6 Copper	No. 6 Copper Clad	No. 8 Copper Clad
4-Ampere circuit	$16.22	$11.76	$13.71	$10.63
5-Ampere circuit	16.46	12.14	14.55	11.98
6-Ampere circuit	16.75	12.60	15.57	13.59

It will be noticed that in all three cases both the No. 6 and No. 8 copper clad wire show a lower annual cost than No. 4 copper; that in the 4 and 5-ampere circuits No. 8 copper clad wire shows a lower annual cost than the No. 6 copper, and that in the 6-ampere circuits the additional annual cost for No. 8 copper-clad wire is only 99 cents.

Labor has been omitted in the above comparisons on the assumption that it would be the same for both copper and copper clad wire. However, as a matter of fact, the cost of stringing copper clad wire would probably be less than stringing copper, owing to its lower weight per mile. Neither has there been any credit taken for the lower maintenance costs on a copper-clad wire, nor the saving in revenue which would accrue from the increased insurance of continuity of service given by the use of a stronger wire. These items, while difficult to estimate in dollars and cents, would unquestionably show a distinct saving for copper-clad wire.

There are many other uses for copper-clad wire in the lighting field, particularly primary high-voltage circuits carrying a small amperage for lines reaching suburban points or farming communities.

There are many cases where, if copper is used, the cost of construction would be so high as to make it uneconomical to build lines to reach such small loads. A line built of a small, strong copper-clad conductor with long pole spacings, will give a very low first cost for this work, and yet give a factor of safety

equivalent to that required by the National Electric Light Association specification.

Copper-clad wire is also used for grounding, especially where a 3-phase 4-wire grounded neutral system is employed.

Copper-clad tie-wire is used for both tying in copper-clad and solid copper conductors. When annealed it is dead soft, and being stronger than copper, a smaller gauge can be used.

The process used for the manufacture of copper-clad wire is as follows:

A steel billet, 6 in. by 6 in. square, and 30 in. long, after first pickling and cleaning, is dipped into a bath of supermolten copper. The copper is so hot that it heats up the steel billet, and the hot steel billet actually absorbs a certain amount of copper, the copper penetrating the steel to a depth of about one-half inch. The surface of the steel begins to melt and when the billet is withdrawn from this bath, the surface is wet down with a copper iron alloy. This alloyed billet is held in an atmosphere of deoxidizing gas, placed in a mould in which the billet acts as a core, the mould being about 8 in. by 8 in. inside, and a coating of copper about 1 in. thick is cast around the billet. The copper coating welds absolutely to the copper iron alloy. The finished billet, about 8 in. square, is rolled down to a 4 in. by 4 in. wire bar, reheated and rolled to rod of any desired diameter. For wire drawing it is finished at a ⅜-in. rod and this rod is then drawn to wire in the same manner as solid copper.

There is, therefore, no contact between the steel and copper, the copper grading into the steel through a series of alloys. The steel nearest the copper is protected from corrosion by being impregnated with copper. If the end of the copper-clad steel wire or wire rod be subjected to an accelerated corrosion test by boiling in concentrated hydrochloric acid, it will be found that the steel nearest the copper is not attacked at all and only the very center is pitted, and that this pitting in the center will not extend to any depth.

Copper-clad wire is no longer a new and untried material. It was first put on the market in commercial form six years ago. In the telephone business, No. 17 copper clad twisted pair drop wire has practically replaced the old standard No. 14 copper drop wire throughout the United States and in most foreign coun-

tries where American standards are followed, and to-day a considerable amount of copper-clad wire in larger sizes, No. 8, No. 10 and No. 12, is being used for telephone line wire.

In the railway signal field probably 80 per cent of the line wire used for automatic block signals in the last few years has been copper-clad wire. It is used by many railroads for their telephone train-dispatching circuits, the Great Northern alone having now in service approximately 15,000 miles of No. 9 B. & S.

Power transmission engineers have used copper-clad wire for several years for telephone circuits strung on transmission towers, and the material is standard for this purpose with many of the largest engineering firms. It has also been used for power transmission conductors on circuits carrying small loads at high voltage. For long spans, such as river crossings, it is particularly applicable, and is now used in some of the most notable crossings in the country, including the Niagara River. It is also applicable to high-tension railroad crossings, where an extra margin of safety is very essential. In electric railway construction it has been used both for span and trolley wire and for the messenger in catenary construction.

The whole trend of overhead construction is toward stronger and more permanent work and greater emphasis is being laid upon the necessity of uninterrupted service. This wire offers an economical method of obtaining this end in many problems of overhead construction.

DISCUSSION

Mr. Mason, Baltimore: I would like to inquire if there is any difficulty caused by the breaking of this wire on 3-phase, high-tension circuits. Such a report has come to me from certain transmission lines in Tennessee. I am not absolutely positive of the fact, but I am informed that they found it necessary to take some of it down.

Mr. Stevenson: I believe the company referred to is the Tennessee Power Co., which used No. 6 wire. It was a very small sized wire, and they used it in long spans; it was finally taken down to be replaced by quarter-inch, copper-clad, steel

strand wire, which is much more suitable for the length of span they used.

The Chairman: If there is no further discussion of this paper, we will go to the next, "Switching Apparatus for Rural Installations," prepared by Mr. E. B. Merriam, of Schenectady, N. Y. I understand that Mr. Merriam is ill, and that his paper will be read by Mr. J. E. Kearns.

SWITCHING APPARATUS FOR RURAL INSTALLATIONS

INTRODUCTION

Practically all companies operating electric power transmis-on lines possess a number of comparatively large and heretofore ıdeveloped sources of profitable revenue. They may supply ectricity to consumers located adjacent to their transmission ıes but now using isolated power plants. They may supply it ır farming and kindred industries where manual labor has here-ıfore been exclusively employed. They may provide facilities hich will permit of the establishment and successful operation : mills, factories and similar industrial establishments on the out-:irts of large centers where a supply of power at a reasonable ·ice has been previously unobtainable. They may also very lvantageously supply power to mines, quarries, pumping instal-tions and various construction activities adjacent to their lines, here it has been the policy to install temporary prime movers ıd generating equipment.

APPLICATION

These new fields of application, some of which have been :scribed in detail in Mr. J. F. Kearns' paper, entitled "Elec-ic Service in Towns of Less Than 5000 Inhabitants," together ith the character of supply each will demand, are grouped Table I.

TABLE I

APPLICATIONS OF RURAL SWITCHING EQUIPMENTS

ısumers	Applications	Character of Load	Type of Substation	Illustrations
nall towns	Street lighting Commercial lighting Water supply Power Railways Household devices	Similar to urban service	Semi-portable	Fig. 1
ırms	Outlined in previous papers	Regularly Intermittent Cyclic Load	Semi-portable or portable	" 4 " 5

Fig. 1

FIG. 2

Consumers	Applications	Character of Load	Type of Substation	Illustration
Mines and quarries	Cable ways Compressors Crushers Drills Hoists Illumination Locomotives Pumps Ventilating fans	Regular load	Semi-portable and portable	Fig. [illegible]
Pumping installations	Irrigation Refrigeration Water supply	Regular Flat load	Portable or semi-portable	Fig. [illegible]
Manufacturing plants	Heat Power Light	Regular Day load	Semi-portable	

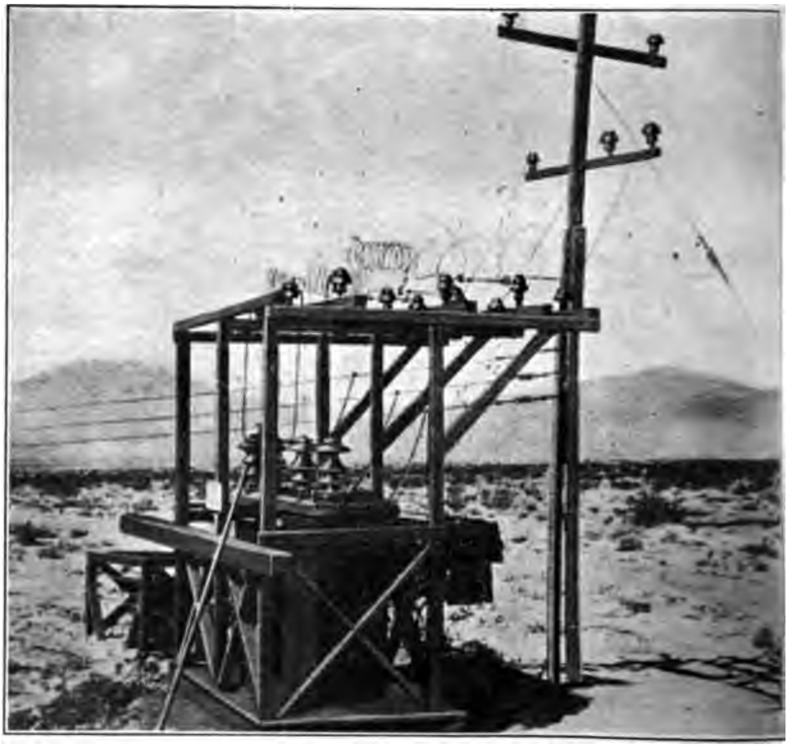


FIG. 3

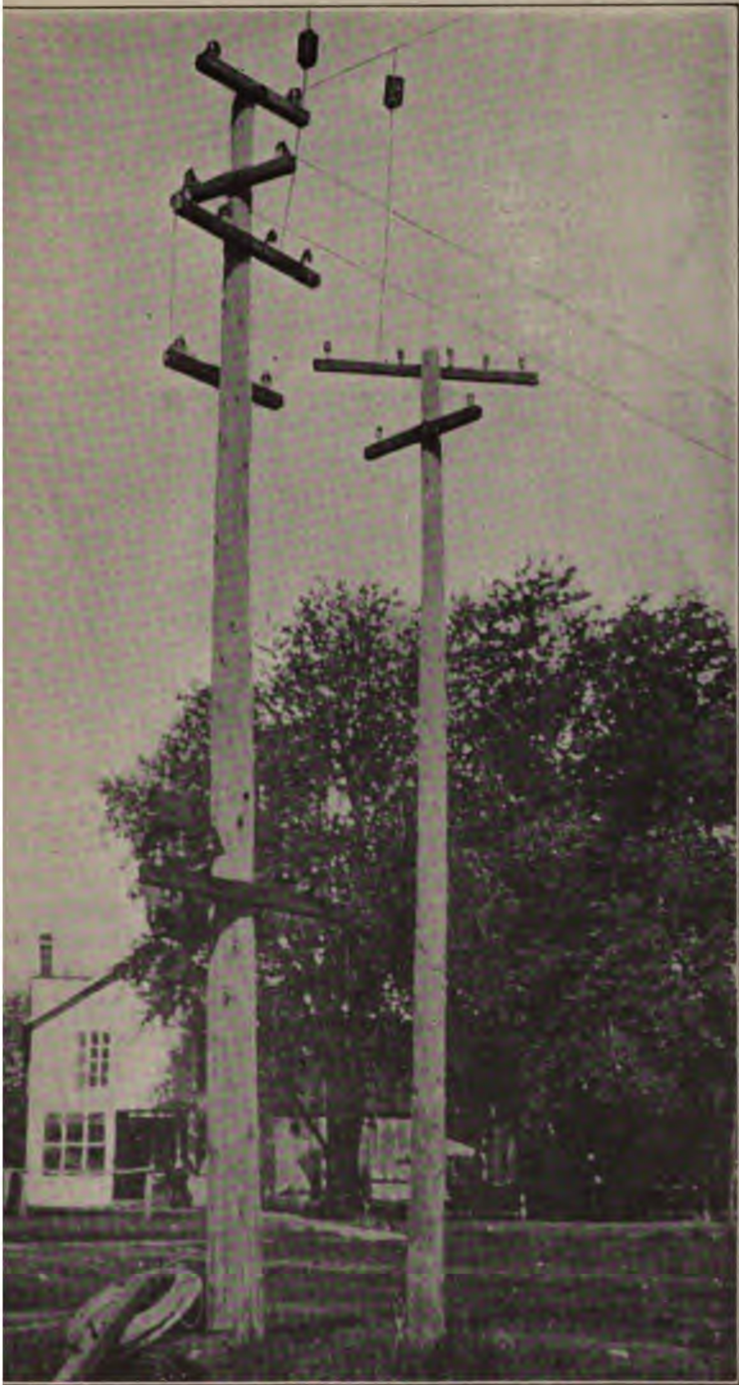


Fig. 4

Consumers	Applications	Character of Load	Type of Substation	Illustration
Contract jobs	Cable ways Compressors Concrete mixers Cranes Dredges Drills Hoists Illumination Locomotives Pumps Shovels	Irregular Intermittent Day and night load	Portable	Fig.

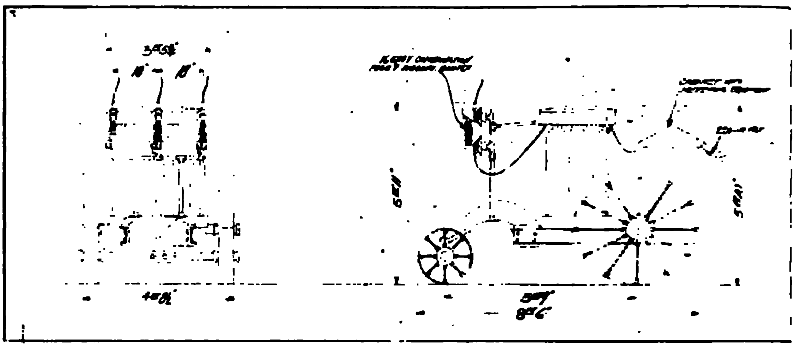


FIG. 5

EQUIPMENT

The wide field just outlined has been opened to operating companies by the development of efficient, reliable and inexpensive outdoor substation equipments. They include outdoor transformers, fuses, switches and other devices recently placed upon the market by electrical manufacturing companies. The equipments are shipped complete, and permit supplying power from transmission lines operating at pressures up to and including 110,000 volts. The minimum economical sizes of installations for various line pressures is given in the following table:

Line Pressure in Volts	Substation Rating in kv-a. 3-phase
2,300	3
4,000	3
6,600	3
11,000	10
16,500	25
22,000	25
33,000	25
44,000	50
66,000	100
88,000	250
110,000	400

In general, the equipments consist of the following groups:

(1) A suitable supporting structure

(2) Primary disconnecting switches, fuses and other protective apparatus

(3) Step-down transformer

(4) Secondary switching and measuring apparatus.

SUPPORTING STRUCTURE

The equipments are made both semi-portable and portable, the supporting structure being especially designed for each case. For permanent installations the semi-portable type is recommended. For lines of comparatively low pressure, a single pole, similar to the standard adopted for the transmission line, is preferable, with the apparatus arranged as shown in Fig. 17. On lines of moderate pressure, a suitable tower made of galvanized iron or steel may be used to carry all the apparatus except the secondary switching and measuring equipment. The latter is placed in a switch house (Fig. 12) located on the ground (Fig. 16). For installations with primary pressures at 45,000 volts and above, the pole or tower may support only the primary switching and protective equipment, the transformers and the secondary switch house being located on the ground (Fig. 6).

Portable substation equipments for supplying power to contractors, farmers and other consumers, whose apparatus is continually being moved from place to place, may be mounted on wagons, railway cars, floats, drags, etc. Figs. 3 and 5 show two of these equipments mounted on a drag and a wagon, respectively.

PRIMARY SWITCHES

Primary disconnecting switches for these equipments are shown in Figs. 7, 8 and 9. The latter, which is especially adapted for outdoor service under extreme weather conditions, is a modified lever switch design. It is provided with a mechanism for raising and lowering the blade in a vertical plane by the rotation of a handle, thus permitting minimum spacing between the poles and easy operation. It is equipped with goat-horn arc deflectors and is designed to permit the operation of one, two or three poles as single, double, or triple pole units. The operating handle may be located at any convenient point

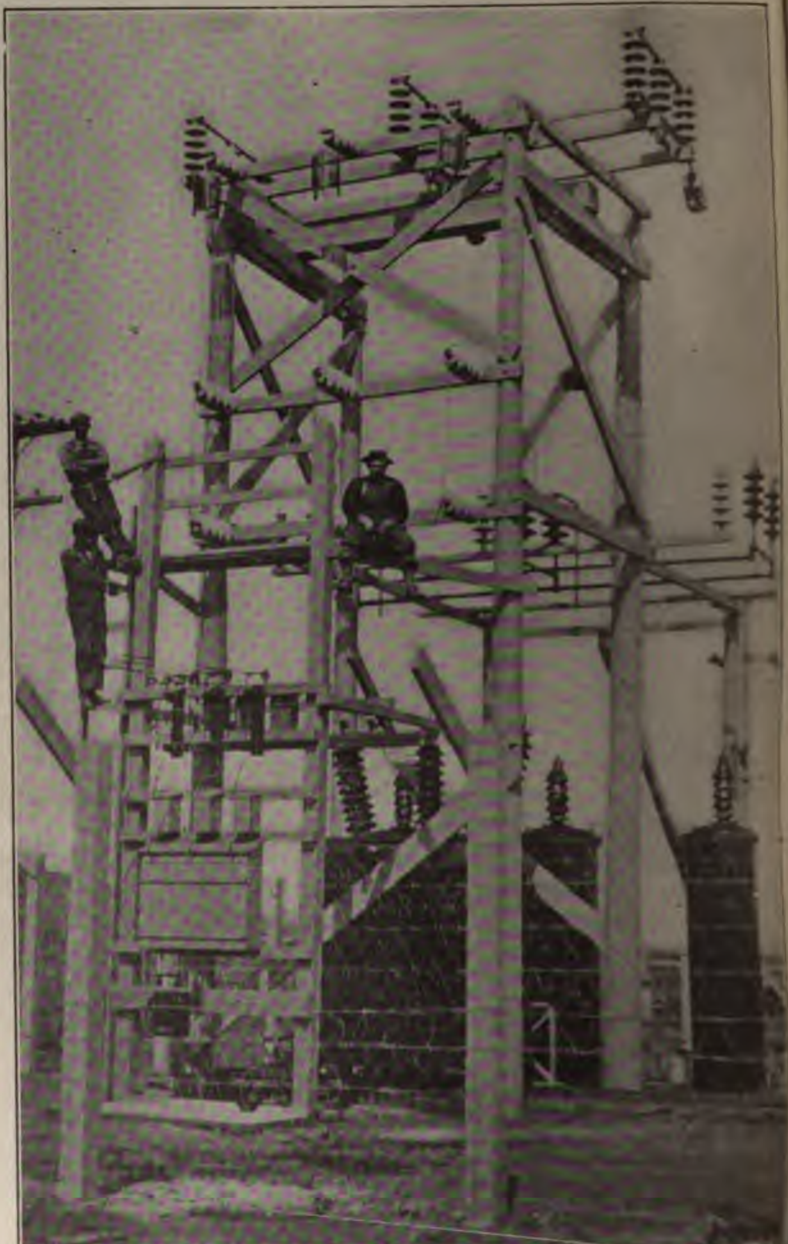


Fig. 6

and is connected to the switch mechanism by suitable bell cranks and gas pipe. It may be locked in the open or closed position by a padlock, similar to railway track switches and signals.

PRIMARY FUSES

Some primary fuses for this service are shown in Figs. 10 and 11. The former employs the well-known goat-horn principle for rupturing the arc when the fuse operates. It has several objectionable features, however, since it is found that the arcs rising along the horns are often long and of large volume, and are readily disturbed by air currents. As a result, unless the phases

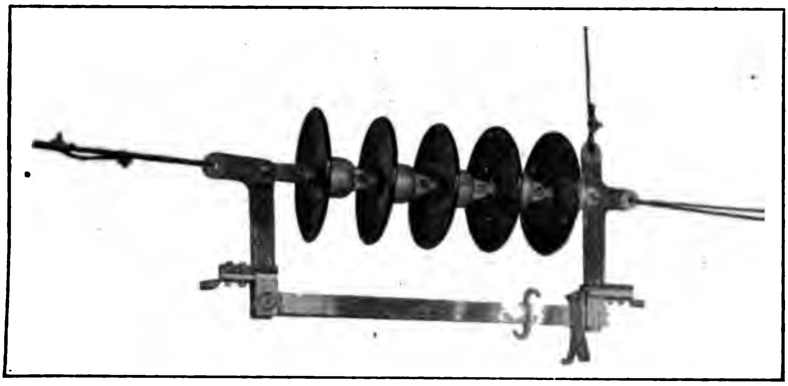


Fig. 7

are spaced very far apart, the arcs are likely to blow across and short-circuit the line. In addition, it has been found that when operating on small currents such as will be used with the various installations previously noted, the magnetic field, upon which the goat-horn principle depends, is too weak to start the arc up the horns, and it persists between them. Furthermore, it is well known that these devices, when operating, introduce surges and oscillations in the transmission line and are, therefore, likely to damage nearby transformers and similar apparatus.

A modification of the well-known tube expulsion fuse is shown in Fig. 11. It is provided with weather-proof fuse-holders, readily removable from the clips for reloading, and is designed for either vertical, or preferably horizontal, mounting. The

holders are closed at one end by a readily removable cap to which is attached the fuse wire. The latter is stretched through the interior of the holder and fastened to the outside at the open end. When overloaded, the fuse melts and forms a gas under high pressure which expands rapidly and blows the arc out of the holder. This design is the result of considerable experimental work and practical experience covering a long period of time.

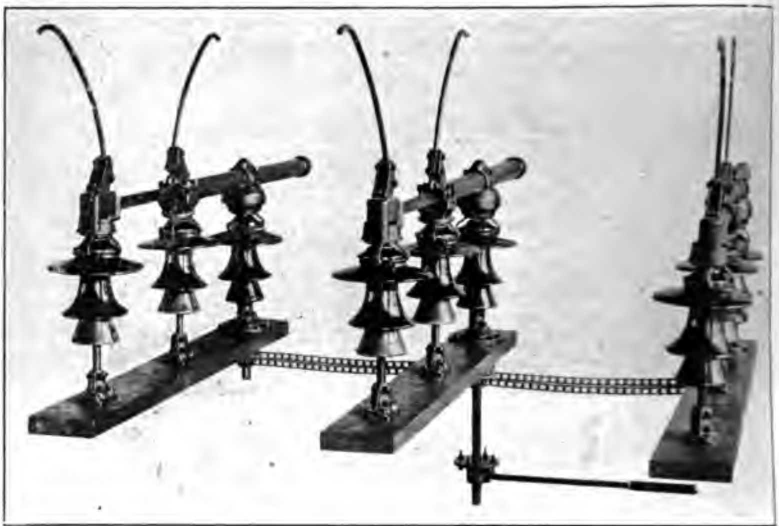


FIG. 8

Another type of fuse draws the arc formed on overload into various liquids which extinguishes the arc and clears the circuit.

LIGHTNING PROTECTION

Lightning protection for these equipments has been very carefully considered. The horn-gap type with one side connected to ground through a suitable resistance has been proposed. It is inexpensive and effective, but unfortunately it introduces destructive oscillations and surges in the main circuit, hence it cannot be recommended for this service. The electrolytic cell or aluminum arrester will give adequate protection, but,

unfortunately, its cost is too high for the installations which have been considered. A new form of lightning arrester, which is now being developed, promises to be reliable, effective and inexpensive and should satisfactorily solve the lightning protection problem for small installations.

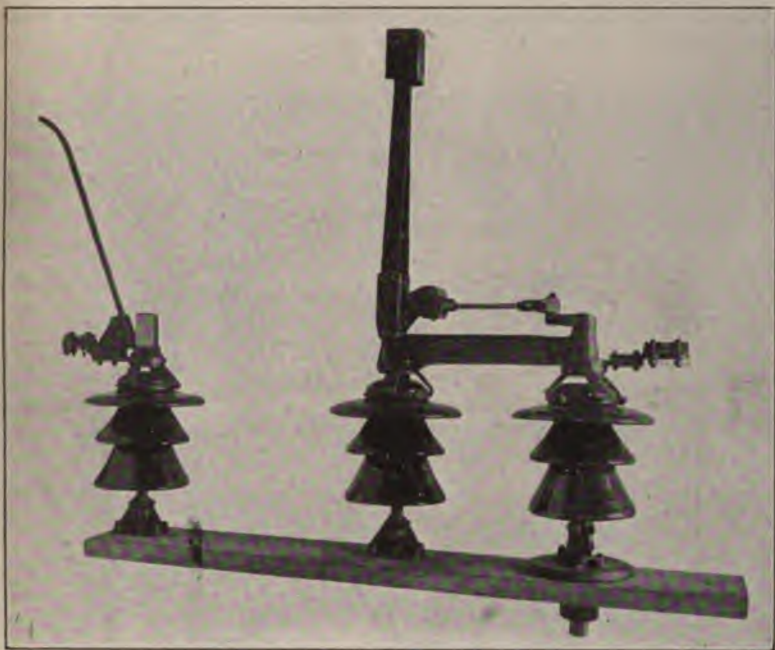


Fig. 9

TRANSFORMERS

The transformers supplied with these equipments are single-phase or 3-phase units, oil-insulated and generally self-cooled. They are especially designed for outdoor service under the most severe climatic conditions and are provided with special insulation in order to withstand the arduous character of the service demanded.

Transformers below 25-kilovolt-ampere capacity are supplied in smooth cast-iron tanks. Above 25 kilovolt-amperes and up to 750 kilovolt-amperes, self-cooled transformers are supplied with corrugated sheet steel tanks, as the largest of these sizes if made

of cast-iron would be too heavy and bulky. From 750 kilovolt-amperes to about 2500 kilovolt-amperes, the necessary radiating surface for self-cooled transformers is obtained by compounding the corrugation, or by the "tubular" or "pipe tank." The latter consists of a boiler-plate tank having the ends of a double row of vertical steel tubes welded into it at the top and bottom. Above 1500 kilovolt-amperes, transformers are usually water-cooled.

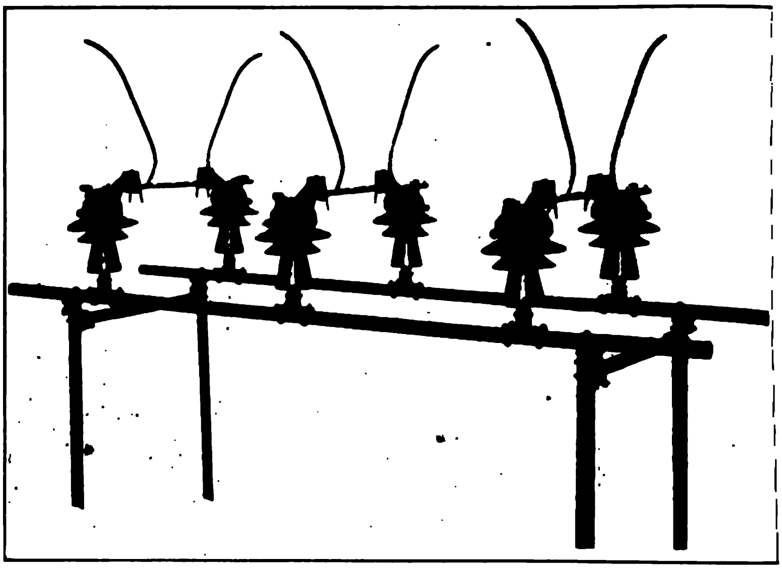


Fig. 10

Transformers for pressures below 17,500 volts have their leads brought out through porcelain bushings set in or underneath the rim around the top of the tank (Fig 17). For pressures above 17,500 volts the leads are carried vertically upward through the cover (Fig. 16) and are protected from the weather by petticoated porcelain coverings.

SECONDARY EQUIPMENT

The secondary switching and measuring equipment consists of the following apparatus:

Disconnecting switches
Automatic oil-switches or fuses

Watt-hour meters
Current and potential transformers.

This may be mounted on a steel or slate switchboard and enclosed in a wooden or preferably steel switch-house. Fig. 17 shows a switch-house for use on a distributing circuit whose pressure is 110/220 volts. It may be readily mounted at any convenient point. The incoming and outgoing leads pass through

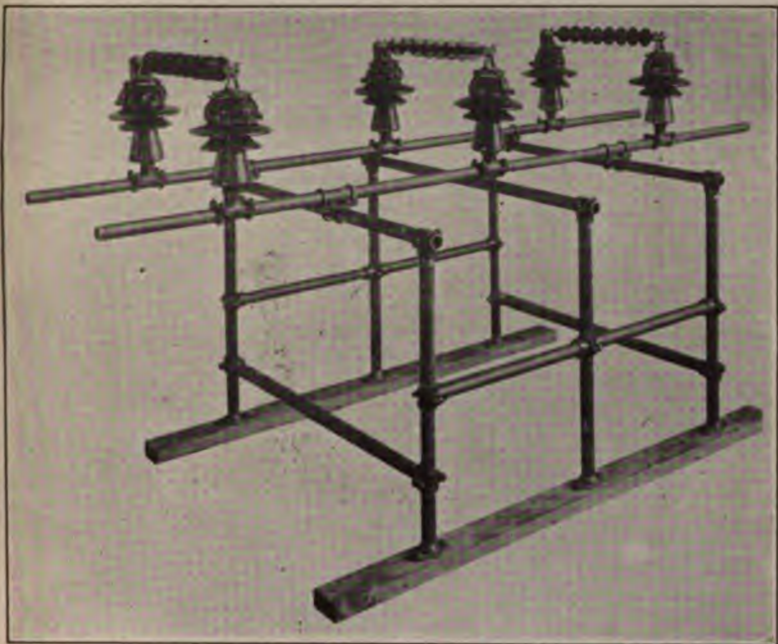


FIG. 11

bushings fixed in the sides, and a door and padlock are provided for securing the contents against marauders. A lever switch with enclosed fuses mounted on a slate base furnishes combined disconnecting and overload protection to the secondary circuit. A watt-hour meter connected directly to the circuit, without the intervention of current and potential transformers, measures the current supply.

A switch-house for 2300-volt secondary distribution is shown in Fig. 12. The house is built of sheet steel

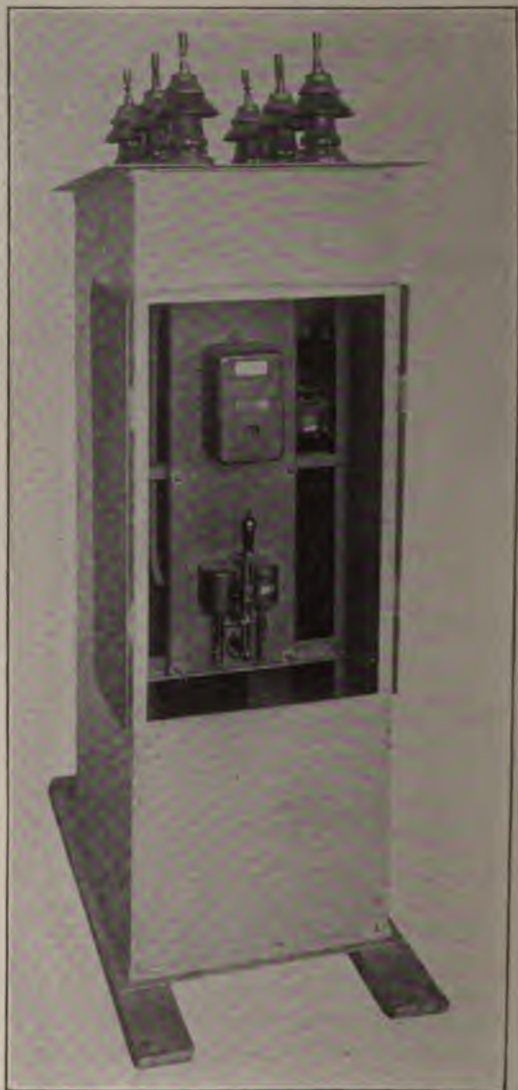


FIG. 12

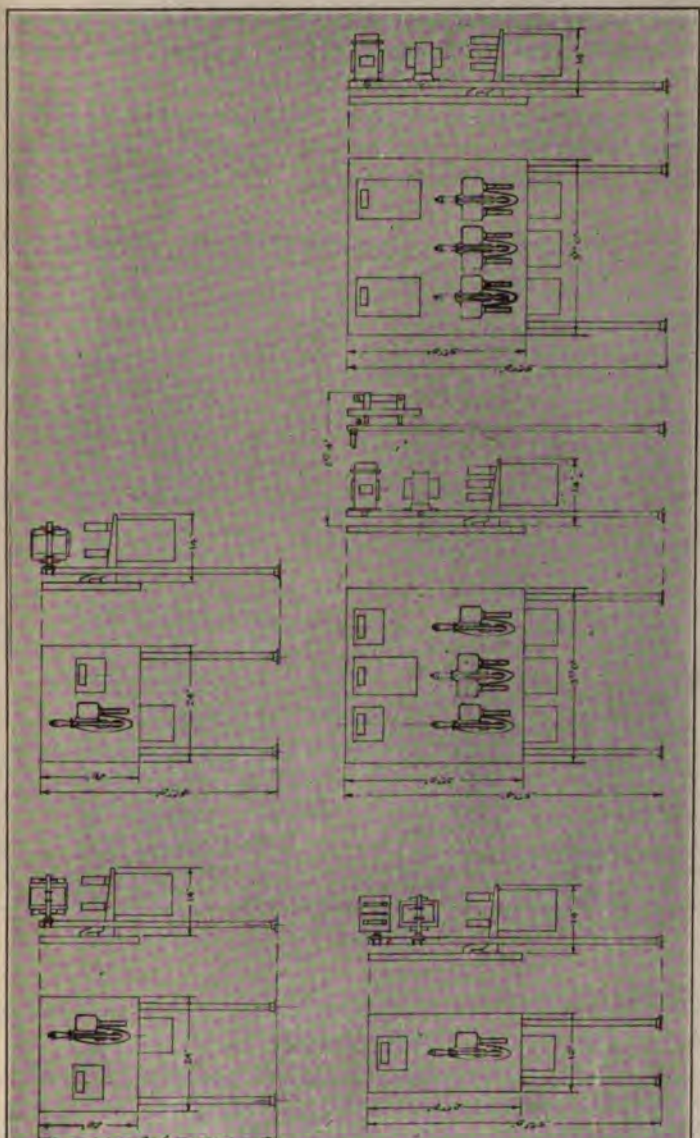


Fig. 13

secured to a structural iron framework and mounted on skids to facilitate transportation and provide a foundation. It is provided with padlocked doors at both the front and the rear, giving ready access to all parts. It contains a slate panel on which are mounted the disconnecting switches, automatic series trip oil-switch and watt-hour meter, the latter provided with conveniently located test terminals. The necessary current and potential transformers are mounted on one of the interior side

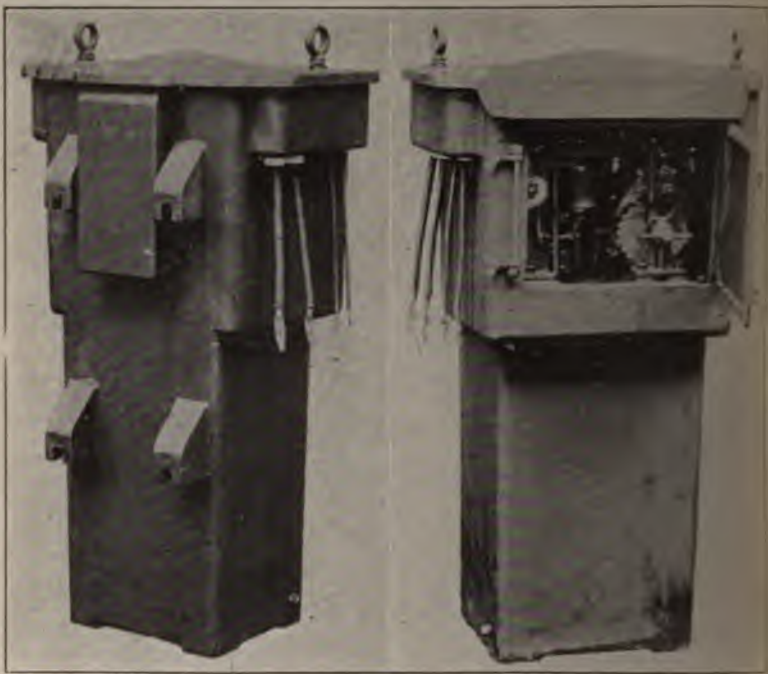


Fig. 14 Fig. 15

walls. It is provided with terminals fastened to the roof to which all of the interior apparatus is connected.

Switch houses are shipped completely equipped and wired. It is, therefore, necessary only to place oil in the oil-switches, when they are so equipped, and attach the incoming and outgoing lines to the exterior terminals in order to have the house in commission. Switch-houses are designed to be equipped

with various standard forms of panels, a few of which are shown in Fig. 13. These provide for single and 3-phase commercial lighting, street lighting, 3-phase power and many other standard distribution circuits.

POLE-TOP REGULATORS

In connection with these equipments, the recently developed pole-top regulators, Figs. 14 and 15, may be used to considerable

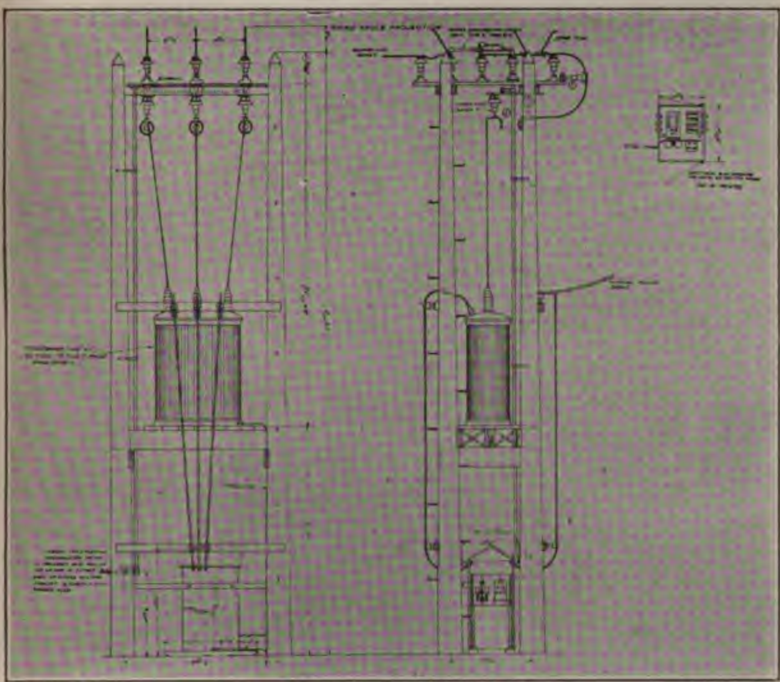


FIG. 16

advantage, particularly for constant pressure lighting circuits. The regulator is of the induction type, automatic, entirely self-contained and has no arcing contacts. It is operated by a small single-phase motor kept in continuous operation and connected to the regular shaft by mechanical means. It is controlled by a voltage relay which operates without the use of arcing contacts. This design of regulator is at present on the market in the 2.3-

kilovolt-ampere, 2300-volt, 60-cycle capacity only. It will control the pressure of a 10-ampere feeder from 10 per cent above to 10 per cent below normal voltage. The voltage relay is designed for 115 and 230-volt, 60-cycle circuits, and its series resistance

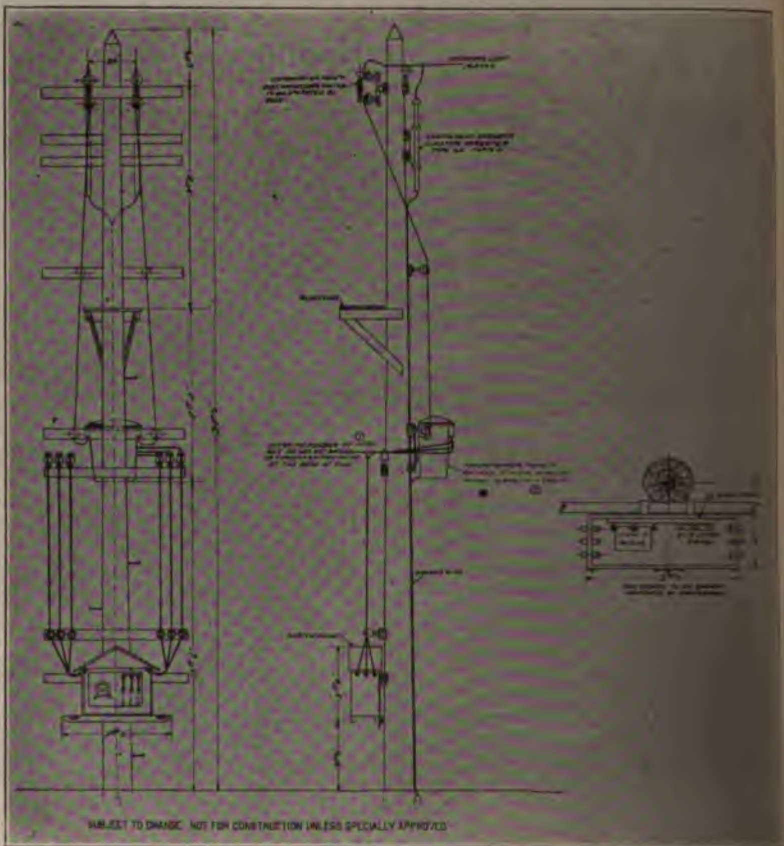


FIG. 17

is provided with several taps so that any voltage up to 15 per cent above or below normal may be used. It is not designed for line-drop compensation but may be used with a standard external compensator.

Fig. 18

PORTABLE GENERATING EQUIPMENTS

In addition to the above equipments, which depend for supply of electricity on a permanent power installation at convenient point, there has been placed upon the market of portable generating equipments. These consist of a ga engine-driven generator mounted on a wagon which m drawn by horses to the point at which power is desired. equipments are particularly adapted for the following clas service.

(1) Breakdown auxiliary service
(2) Temporary peak loads
(3) Construction work
(4) Replacement during rehabilitation of old statio
(5) Assisting in new-business solicitation,

and should form an efficient and useful auxiliary to all tra sion line operators.

CONCLUSION

The developments herein described have forged anoth in the chain of universal electrification and their appli should be of distinct benefit to central-station companie consumers.

(Adjourned *sine die.*)

EXHIBITORS' INDEX

Sangamo Electric Co.
John A. Roeblings' Sons Co.
Simplex Electric Heating Co.
Southern Exchange Co.
Standard Underground Cable Co.
Thompson Electric Co.
Transportation Committee N. E. L. A.
Tungstolier Works of General Electric Co.
Valentine-Clark Co.
Wagner Electric Manufacturing Co.
Western Electric Co.
Western Water Supplies Co.
Westinghouse Electric & Manufacturing Co.
Westinghouse Lamp Co.
Westinghouse Machine Co.
Weston Electrical Instrument Co.
Wilkinson Co

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RELIABILITY
ECONOMY